Towards a Harmonized Framework for High Reliability Organisations

A Ph.D. Thesis

By

Agwu Emele Agwu

The thesis is submitted in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy of the University of Portsmouth

Department of Operations and Systems Management

Faculty of Business and Law

January 2018

Abstract

Within the last few decades, there has been an exponential growth in technologies and process interdependencies within organisations. The period has additionally witnessed accelerated incidences of disasters. Despite operating with tightly interdependent processes and complex technologies where failures could potentially result in disasters, high reliability organisations have continued to record high levels of performance in organisational reliability and safety. Given the increasing havoc wrecked by disasters on organisations, people, and the environment, a framework is required to transfer learnings from high reliability organisations to diverse organisations. This research investigates the extent to which the reliability of organisations can be measured, and the extent to which this measurement can be applied to diverse organisations. Research on high reliability organisations have been mostly conducted through theoretical abstraction and mostly performed in single organisations, with little empirical evidence to support the generalizability of the conclusions. They have been mostly reactive, analysing incidents after the fact, often with retrospective predictability. This research used a mixed methods approach to study eight organisations, in three industries. It combined the objectivity of the survey strategy with the subjectivity of in-depth interviews to obtain balanced data sets that best serves its exploratory nature. It proposed the organisational reliability maturity model that defines baseline measurements and tracks the progression of organisations through different maturity levels. It developed a framework for organisational reliability maturity to identify organisational maturity levels, predict improvement or regressive potentials, benchmark organisations, and develop processes for organisational learning and performance improvement. This research expands existing knowledge in organisational research and opens up new areas of knowledge. It enhances the standardisation and generalisability of the high reliability organisation theory. It enables benchmarking, organisational learning and performance improvement. Finally, it eliminates the retrospective predictability of incidents causative factors and enhances the ability of organisations to predict the potential for incidents. It is hoped that these would help to make organisations more resilient, reduce incidents and disasters, and ultimately safeguard humanity.

Declaration

Whilst registered as a candidate for the above degree, I have not been registered for any other research award. The results and conclusions embodied in this thesis are the work of the named candidate and have not been submitted for any other academic award.

I hereby declare that the research documented in this dissertation has been undertaken by the author, and that any work included in it that was not undertaken by the author has been appropriately attributed.

Word count 68,634

Agwu Emele Agwu

Table of Contents

List of Tables

List of Figures

List of Equations

List of Abbreviations

5S – 5 Stages of maturity from Silent, Starter, Stable, Sustain, Summit

A

Airprox – Air Proximity Hazard

B

BS – British Standard

C

CAA – Civil Aviation Authority

CIA – Central Intelligence Agency

F

FORM – Framework for Organisational Reliability Maturity

H

HSE – Health Safety and Environment

HRO – High Reliability Organisations

I

IET – Institute of Engineering and Technology

INSAG - International Nuclear Safety Group

M

MFA – Ministry of Foreign Affairs of Ukraine

MIC – Methyl Isocyanate - a highly toxic and irritating intermediate chemical in the production of carbamate pesticides, and a principal toxicant in the Bhopal disaster.

N

NASA - National Aeronautics and Space Administration

O

ORM^2 – Organisational Reliability Maturity Model

R

RBMK 100 - a class of graphite-moderated nuclear power reactor designed and built by the Soviet Union

T

TCDD - 2,3,7,8 –Tetrachlorodibenzo-p-dioxin: a colorless solid with no distinguishable odor at room temperature. It is usually formed as a side product in organic synthesis and burning of organic materials.

U

UK – United Kingdom

W

WHO – World Health Organisation

Acknowledgements

My sincere appreciations go to everyone that supported me throughout the duration of this PhD.

I would like to specially thank my supervisor Professor Ashraf Labib for all his advice, his unalloyed support, and the regular coaching sessions over the years. His consistent encouragements for me to think through situations helped keep me on track when I could have otherwise been side-tracked.

I would also like to thank my second supervisor Professor Alessio Ishizaka for his candour, insightful comments and balanced perspectives. To Dr Sara Hadleigh-Dunn, I say thank you for being part of my annual reviews and for all the useful contributions and advice.

I thank the University of Portsmouth Ethics Committee for reviewing the research and pointing me in the right direction. A special thanks to Dr Debbie Reed for helping me through the requirements of the ethics committee, and to Dr Judi Rich for all your assistance during the research process and beyond.

I acknowledge the managements of the organisations that graciously allowed their staff to participate in the survey. I thank the gatekeepers and all the respondents.

I also specially thank my family for their support for the duration of this study. To my dear wife Chichi, and my children Kingston, Kayla, Keshawn and Duke, I missed some moments in your lives while stuck in the basement library, poring over countless books and papers. Once again, Daddy is back!

Finally, I thank the Almighty God for seeing me safely through the survey administration period despite the security and logistics challenges prevalent at the

locations during the period; and for providing the resources and good health, without which this project would have been impossible.

Dissemination

Agwu, A., Labib, A, Hadleigh-Dunn, S., (2018) Disaster Prevention through a harmonised framework for High Reliability Organisations, Journal of Safety Science (Paper under review)

Agwu, A., Labib, A, Hadleigh-Dunn, S., (2017) Towards a harmonized framework for High Reliability Organisations. Conference presentation, International Conference of System Reliability and Safety, December 20 – 22 Milan, Italy

Agwu, A., Labib, A, (2018) Adopting the High Reliability Organisations model to improve safety, to be presented at the Annual Conference of the Society for Maintenance and Reliability Professionals Oct 22 – 25, 2018, Orlando Florida, USA.

Agwu, A., Labib, A, (2018) Maturing assets towards higher reliability, to be presented at the Annual National Conference of the Plant Engineering and Maintenance Association of Canada, Moving Train 2018, Sep 24 – 27, 2018, Ottawa Ontario, Canada

CHAPTER ONE

Introduction

1.1 Research Background

There is an old English saying "*don't spoil the ship for a ha'p'orth of tar*", which means that one should not risk the failure of a large project by trying to make savings on trivial things. Before ships made of steel and metal alloys became common, they were made of wood. Sailors used tar to prevent water from getting in the gaps between the planks and the wood, and would normally keep some tar in the ship. A half penny worth of tar could plug a gap that could potentially sink the ship if left unattended to. This saying also suggests therefore that catastrophic failures could be prevented by implementing minor but timely activities. Studies have shown that most catastrophic failures have been caused by series of seemingly minor individual, technical, and lack of organisational mindfulness (Gilbertson et al; 2011; Labib & Read, 2013; Labib & Read, 2015; Labib, 2014; Savioja et al, 2014; Waring, 2015; Harvey et al, 2016; Li, 2016). These incidents could perhaps have been avoided had the organisations mindfully invested in "*a ha'p'orth of tar*".

Perrow (1984) had argued in favour of the inevitability of disasters no matter the efforts individuals and organisations would devote to prevent them. To him, as long as an organisation is characterized by complex technologies and a tight coupling, where a problem in one part of the process will impact other parts of the process, the inevitability of disasters are unavoidable. Some other researchers contrasted this rather pessimistic point of view, with the consideration that some organisations have continued to operate at top quartile levels in organisational reliability and safety despite operating with complex technologies and with tightly coupled processes. These organisations operate in highly hazardous environments, where minor lapse in judgment or process failure could potentially result in catastrophic failures; yet continue to record consistent high level performance in organisational reliability and safety. They continuously avoid failures, and are mostly designed such that eventual failures do not result in catastrophe. Should catastrophic failures eventually occur, these organisations are well equipped to withstand the consequences and are able to re-engineer themselves for future competitiveness. Weick & Sutcliffe (2007) called them *High Reliability Organisations* (HROs).

This research leverages on the HRO theory to propose how organisations could operate in ways to make their processes more reliable and with potentially less incidents.

1.2 Summary of Current HRO Research

Most of the work on HROs has been concentrated on understanding the concept as it relates to specific industries or organisations. The industries have included transportation, aviation and military (Roberts et al, 1994; La Porte & Consolini, 1998; Busby, 2006; Jeffcott et al, 2006; O'Neil, 2011), space (Schulman, 2008), energy (Hoffmann et al, 1995; Miller, 2009; Hopkins, 2009; Lekka & Sugden, 2011), nuclear (Bierly & Spender, 1995; Ashley et al, 2009), and fire and disasters (Keller, 2004; Weick & Sutcliffe, 2007; Berardi, 2010). A lot of research has gone into the application of the HRO theory in the healthcare industry (Baker et al, 2006; Frankel et al 2006; Madsen et al, 2006; Roberts et al 2005; Stralen et al 2006; Tamuz & Harrison, 2006; Costella et al, 2009; Riley, 2009; Samuels, 2010; Sutcliffe, 2011). Other industries where attempts have been made to apply the HRO theory include education (Stringfield, 1995; Taylor & Angelle, 2000; Azzaro, 2005; Bellamy et al, 2005; Stringfield et al, 2008), food retail (Ciravenga & Brenes, 2016), and virtual organisations (Grabowski & Roberts, 2016). Some research has aimed at comparative analyses with other concepts such as resilient engineering (Aven & Krohn, 2014; Righi et al, 2015; Bergstrom et al, 2015; Haavik et al, 2016; Harvey et al, 2016; Le Coze, 2016).

Bundy et al (2017) in their work on crisis management noted that some HRO research have also focused narrowly on organisational reliability limiting factors. Such limiting factors according to Bundy et al (2017), include the emotional and cognitive limitations of managers (Kahn et al., 2013; Roux-Dufort, 2007); the number of organisational disruptions (Rudolph & Repenning, 2002); the availability and use of organisational resources (Marcus & Nichols, 1999); and the roles of practices and structures used to promote reliability (Lin et al, 2006; Vogus & Welbourne, 2003). All these research were mostly theoretical exercises that were not backed by empirical data. Some other researchers have attempted to implement the HRO theory in specific organisations such as healthcare (Hines et al, 2008; Hales, 2013). Hales & Chakravorty (2016) attempted to implement the HRO theory using a soft research method approach, moderated with mindfulness techniques. This was also in a single organisation within the health care sector, and therein lies the gaps. First, these mostly case based researches have concentrated on certain organisations, thereby limiting their generalisability. Secondly, there is no evidence of a generalizable empirical research that studies diverse organisations with respect to organising for reliability. Bundy et al (2017), Levenson et al (2009), and Bigley & Roberts (2001), noted this gap in their respective studies. They noted the lack of specificity of existing research in the HRO theory, the abstract nature of the theory, and the need for a "comprehensive and detailed treatment" of high reliability organisations. This research hopes to close these gaps. The next section explores these gaps in more detail and lays the groundwork for the steps the research has taken towards closing them.

1.3 Gaps in Current HRO Research

One of the gaps identified with current research in the HRO theory is the lack of evidence of a research conducted across different types of organisations to test the HRO theory. Such research would not only provide a balanced perspective about the HRO theory, but would also show the extent to which the theory could be standardized across organisations with diverse characteristics. Another gap is that most HRO researches have been reactive, mostly studying how the theory could have helped avoid catastrophic events retrospectively from a theoretical perspective. There is no research directed at understanding how reliable organisations are and predicting the potential behaviour of the organisations given prevailing conditions. The ability to predict the potential behaviour of an organisation would assist the organisation to develop improvement processes and actions to mitigate potential incidents. Furthermore, research has been limited to the traditional large HROs with complex technologies and potential for far reaching catastrophic failures such as the nuclear industry (Labaka et al, 2015). Traditional HROs here refers to those organisations conventionally regarded as HRO by the initial HRO researchers. Some may argue that implementing the HRO theory in non-traditional HRO related industries does not make financial sense. They however forget that most of the catastrophic failures in recent history have come from organisations not considered as traditional HROs. These have included the oil and gas industry, transportation industry, mining, chemical process industry, and buildings. A brewery or restaurant chain for instance might not be as technologically complex as a nuclear energy organisation, neither are their processes as hazardous nor tightly wound as the nuclear organisation. However, certain failures in the process of a brewery or a restaurant chain could potentially lead to (and as will be shown in chapter three, have actually led to) multiple mass fatalities. The same could be said of public utility systems such as electricity and water. They would therefore require high levels of reliability to sustain their operation more efficiently, yet no effort has been made by previous research to use the HRO theory to improve their reliability.

The final gap stems from the fact that no research available has shown how to measure the mindfulness of the organisations, or how the organisations can sustain their levels of mindfulness or progress through the stages of maturing towards a higher level of reliability. The world stands to gain from the extension of the theory to diverse organisations, especially given recent vagaries in the world economy. Organisations would become better assured of their ability to deliver their targets and goals with minimal incidents.

To fill the gap of lack of evidence of a research conducted across different types of organisations to test the HRO theory, this research has conducted research in 8 different organisations in 3 different industries. Given that these organisations have different and often contrasting characteristics, the research set out to obtain a wide range of data upon which to develop a robust framework. In addition to expanding the scope of current HRO research, this study has developed an organisational reliability maturity model (ORM^2) and the framework for organisational reliability maturity (FORM) that would identify the level of reliability of an organisation and predict the potential for incidents based on reliability trends. This would fill the gap of the retrospective nature of most HRO research. The model and framework would also close the final gap of inability of current research to proffer a methodical approach improving the reliability of organisations. The framework leverages on the model to develop a step wise approach to assess the current organisational reliability maturity levels of organisations, identify their potentials to improve or retrogress, and recommend improvement or sustainability behaviours. This step wise approach would be beneficial to organisations both for self-auditing and for external benchmarking, as well as to facilitate continuous improvement initiatives.

1.4 Research Questions

Given the gaps identified in the previous section, the research has proposed two research questions, the answers of which are expected to help to close the identified gaps.

- To what extent can the reliability of organisations be measured?
- Can these measurements help diverse organisations become more mature?

According to often quoted conventional wisdom, "*you can't manage what you can't measure*", or as some others choose to put it, "*you can't improve what you can't measure*". To understand the reliability of organisations, there must first be some measurement criteria that will define what is being measured and the scope to which the measurement is expected to cover. The first research question, "*to what extent can the reliability of organisations be measured"* aims to investigate the possibility of developing a measurement framework for high reliability organisations. Such measurement would establish the baseline from which improvement and sustainability initiatives could be developed for the organisations. The framework will assess the degree of reliability of individual organisations and create a platform from which improvement opportunities could be explored.

The measurement will thereafter set the stage to answer the second research question: "*can these measurements help diverse organisations become more mature?"* This question aims to evaluate the applicability and usability of the measurements to improve the behaviour of the organisations. The framework establishes the best practices expected from highly reliable organisations. These best practices become the benchmark to help organisations assess their variance from the desired. Furthermore, effective measurement assures the potential of the framework to predict the degree to which the reliability of organisations could potentially improve or retrogress. In answering the second research question, the research establishes the ability of the measurements to suggest possible specific improvement actions the organisations could adopt to improve its maturity.

Both questions together, help the research close the identified standardization gap by making the framework objective and repeatable. Diverse organisations could therefore replicate the research, ascertain their maturity level, benchmark themselves against desired standards, implement continuous improvement actions, and adopt further actions to enhance the sustainability of achieved maturity levels.

1.5 Research Aim and Objectives

This section leverages on the discussions surrounding the research questions and identifies what the research aims to archive, as well as the objectives it has set out.

The aim of the research is to develop a harmonized framework for organisational reliability measurement and apply the high reliability organisation theory to improve the maturity of organisations.

To achieve this aim, the research sets out the following objectives:

- ***Collect a balanced data set:*** The research would collect objective and subjective data from different organisations in different industries and with diverse characteristics to help establish a wide range of data to base its assumptions on. The wide range of data would help increase the validity of the assumptions and the conclusions the research would make.
- ***Develop a model to map the maturity behaviour of organisations:*** The research would develop an organisational maturity model (ORM^2) that will identify specific reliability enhancing behaviours in organisations for each of the 5 high reliability organisation principles. The model will map these behaviours into 5 maturity levels and propose what behaviours would be expected from organisations in different maturity levels. These behaviours would progress incrementally as the maturity level improves. The model will comprise of 25 boxes that corresponds to the 5 HRO principles against the 5 maturity levels. It will map the 5 HRO principles on the *x - axis* against the 5 maturity levels on the *y – axis.* It will show the position of each organisation at any given time, as well as the position of the organisation against its peers.
- ***Develop a standardized framework to assess the reliability of organisations:*** The framework for organisational reliability maturity (FORM) would identify the maturity level of the organisations with respect to the 5 high reliability organisations principles using the behaviours identified in the organisational reliability maturity model (ORM^2). The framework would be replicable and applicable across different organisations with diverse characteristics and in

different industries. Measuring and assessing an organisation's current status is a vital input into the continuous improvement cycle planning stage. To plan for improvement, the organisation needs to assess its current status and understand the current behaviours that are impeding or enhancing its progress towards their desired maturity level. The framework will would be comprehensive enough to measure the reliability enhancing behaviour in each of the 5 HRO principles, and propose a generalized organisational maturity level based on these individual behaviour.

- ***Benchmark organisations against desired behaviours:*** Blackstool et al. (2012) consider benchmarking as "*the process of self-evaluation and self-improvement through the systematic and collaborative comparison of practice and performance with similar organisations in order to identify strengths and weaknesses, to learn to adapt and to set new targets to improve performance*" The framework would establish the maturity enhancing behaviour that is most desirous and considered best in class. These would form the standard behaviour with which organisations would benchmark themselves against. Benchmarking could be against the desired best in class behaviours, or against peers. It could also be used within the same organisation to track behaviours between different units or departments and it sets the stage for organisational reliability continuous improvement exercises.
- ***Predict future maturity levels of organisations:*** The framework would be robust enough to have the ability to predict potential future organisational maturity levels given current behaviours. It would achieve this in two ways. First, as soon as the initial baseline measurements are obtained, subsequent measurements will be compared with the baseline to assess the degree of progress or regression recorded within the period under review. Subsequent measurements would be compared with the preceding measurement to track progress. The second way the framework would predict future maturity of an organisation would be to establish the behaviours that are highly prevalent next to the maturity level. The severity of these behaviours could indicate that the organisation is improving or retrogressing with regards the principle being

reviewed or in general. The research called this the "***pull"*** *and has developed a mathematical function to calculate* the pull for each individual principle and the organisation in general. Results of the *pull* from subsequent measurements would indicate more clearly if the organisation is progressing or retrogressing. It would also show the maturity level towards which the organisation is being "*pulled",* an indication of where the organisation would potentially fall into should current behavioural trend persist.

- ***Develop a standardized framework to help organisations create reliability maturity improvement initiatives:*** Based on the current maturity levels and the pulls, the framework would develop a set of behaviours that would help improve the organisational reliability maturity level of the organisation towards the next level.

The research expects that developing a framework for measuring the maturity levels of organisations with respect to their reliability will not only enhance the knowledge area, but will also form a foundation for organisations to build upon and improve their reliability.

1.6 Theoretical Framework and Research Methods

The research attempts to make a case that those organisations that implement and entrench mindful behaviours into their consciousness would stand better chances of enhanced reliability. It adopts a pragmatist philosophy, combining the positivism of the objective ontological assumptions with the interpretivism of the subjective ontological assumptions to collect and analyse data. It does this because of the multidisciplinary epistemological background of the research, which would require objective and subjective facts to be valid. The objective facts would offer more credibility, would be less open to bias, and would easily be verifiable and replicable. The subjective data on the other hand would be necessary to incorporate a rich and complex view of organisational realities. It would also account for the differences in individual contexts and experiences of the members of the organisation and its members, and would therefore be better equipped to explore the social realties surrounding these social actors.

The research adopts questionnaires as its strategy for obtaining quantitative data. It does so with the assumption that questionnaires are best suited to answer exploratory questions as proposed by the research:

- *To what extent can the reliability of organisations be measured?*
- *Can these measurements help diverse organisations become more mature?*

The research also assumed that questionnaires would offer the best cost effective and least logically burdensome strategy to adopt in its attempt to administer to over 500 proposed respondents across different locations. Finally, the research utilized the narrative inquiry of in-depth interviews as its research strategy to obtain qualitative data. This is with the view to obtaining, complementary data about the underling details behind the objective data. These details would include the experiences, value systems, and biases of the respondents, as well as details of the deeper realities linked with social relationships that define the organisational behaviours.

The research studied eight organisations in three industries, and across two continents between July 2016 and January 2017, using the same research methods. It started with a pilot study to test the proposed data collection methods. The pilot study was done through purposive sampling, and the respondents were demographically stratified to reflect the expected demographic composition of the expected research sample population.

The industries were also purposely selected due to their potential for catastrophic failures, as well as their being different from the available research into high reliability organisations. The organisations were selected to contrast with each other. The selection was based on size, age, organisational spread. For a large organisation selected, a smaller one was identified and included; and for a multinational organisation selected, an organisation with a localized spread will be selected and included. The aim of this was to generate a data set that would show the diversity of the expected behaviours and hopefully help to answer the research questions and address the research objectives.

1.7 Expected results and Research Limitations

The research obtained data from 441 respondents from different and contrasting organisations. It started out with the expectation that 10% to 20% of the respondents would be within the management function; 20% to 40% would be within the supervisory function, and 40% to 60% would be frontline staff. This is in line with the conventional wisdom of employee – supervisor – manager ratio. The research also designed the survey instrument with the expectation of a stratified demographic in terms of years of experience in the industry ranging from below 3 years, between 3 to 7 years, above 7 years and below 15 years, 15 to 25 years, and above 25 years. This demographic distribution is based on a 5 level stratification and assumes that new employees in an industry would spend the first 3 years trying to understand the nuances within and between the different aspects of the industry. Their experience and motivation level is expected to change over their employment life cycle, so will their perceptions and attitudes. After 25 years, most employees would be past their mid-career, as which point, opinions and perceptions would also be different. This stratification therefore has been designed to obtain data from people at different career levels and with diverse perspectives on the social realities within the organisation. This would hopefully provide both depth and balance to the results and the results thereafter. In addition to experience, the research also designed the survey instruments with the hopes of obtaining data from different gender to add more depth. The research expects that different perspectives and biases of the social realities within the organisation could be influenced by gender, and therefore made provisions to analyse the responses with respect to gender. Finally, the research tried to enhance diversity of respondents and depth of results as previously stated by purposively selecting organisations with contrasting characteristics. These choices and assumptions together are expected to generate a rich and well-balanced data grounded in diversity. This would hopefully form the foundation to propose the standardized model and framework to help deepen the studies in the high reliability organisation theory, as well as help organisations tend improve or sustain their organisational reliability maturity.

The framework and the model developed from the results would be called the Framework for Organisational Reliability Maturity (FORM) and the Organisational

Reliability Maturity Model (ORM^2) respectively. The model would map organisations into various stages of mindfulness, and identify clear strategies that would help organisations progress through the various organisational reliability maturity levels. It is hoped that the ORM^2 would become a proactive framework to help organisations sustain and improve their mindfulness, prevent catastrophic events, and remain competitive, while providing a platform for diverse organisations outside the traditional HROs to learn and adopt the HRO principles. By adopting the strategies outlined in this research, diverse organisations, including smaller organisations with simple and seemingly less hazardous technologies and processes could operate mindfully and avoid certain pitfalls that have led to the demise of many organisations.

The key limitation of this research would be the sample size. It was conducted in only 3 industries and 8 organisations, and although the research has a high confidence level, it cannot claim that these industries and organisations are accurate representation of all industries and organisations. In addition, the research would not completely guarantee that it could be seamlessly implemented in other industries; neither would it guarantee that the results would be a reflection of the results from other industries and organisations not yet researched.

Furthermore, the research purposely selected an organisation in Canada within one of the 3 industries being researched for triangulation. Although the behaviour expected from this organisation was expected to be similar to what was expected from a traditional high reliability organisation, it is still not considered a traditional high reliability organisation in the sense of previously published works on the HRO theory. There is the possibility that the assumptions made about HROs might not work when actually tested in a high reliability organisation. These limitations would therefore present gaps in this study that could potentially open up opportunities for further research.

1.8 Structure of Chapters

This thesis is laid out in 6 chapters. Chapter 1 has introduced the research. It has identified some potential gaps and described the how closing the gaps will expand existing knowledge. It outlined the aims and objectives of the research, and outlined how the research will contribute to existing knowledge, open up a new area of knowledge, as well as help organisations begin to develop mindful behaviour that would help improve their organisational reliability maturity. It introduced the research methods and methodology and described the expected results and limitations of the research.

Chapter 2 will review some relevant literature and describe related concepts. It will introduce the concepts of reliability and disasters, and describe some perspectives surrounding safety around disasters. It will also introduce the concepts of mindfulness, the high reliability theory and maturity models.

Chapter 3 will review the methods of data collection and analysis, as well as describe the methodologies behind the methods. Chapter 4 will discuss the results. It will discuss the demographic data and its implications on the research. It will also discuss the results from the perspectives of the HRO theory, and from the perspectives of the organisations.

Chapter 5 will use the results to describe the organisational reliability maturity model (ORM^2) and the framework for organisational reliability maturity (FORM). It will assess each organisation based the organisational reliability maturity model (ORM^2), and the framework for organisational reliability maturity. It will compare the organisations using the framework, and show how the framework could be used for benchmarking. It will finally describe how the organisational reliability maturity model (ORM^2) and the framework for organisational reliability maturity (FORM) could be combined to improve organisations.

Chapter 6 will conclude the thesis. It will summarise the proposed organisational reliability maturity model (ORM^2) and the framework for organisational reliability maturity (FORM) and highlight the contributions of this research to the knowledge and to organisational improvements. Finally, it will show some limitations of the research and highlight some scope for future study.

1.9 Chapter Summary

This chapter has introduced the research. It highlighted the aim of the research *to apply the high reliability organisation theory to improve the maturity of organisations.* It outlined the objectives of the research to include collection of a balanced data set; development of a model to map the maturity behaviour of organisations; and development of a standardized framework to assess the reliability of organisations. It also includes benchmark marking organisations against desired behaviours; predicting future maturity levels of organisations; and the development of maturity improvement plans for organisations.

In addition, the chapter has described existing research within the subject area, and identified some potential gaps within the existing research. The gaps include the lack of research that transcends diverse organisations and industries. Most of the research has been limited to certain types of organisations, including aviation, military, space, and fire departments with nothing to provide a balanced perspective about the HRO theory. Furthermore, most research has been carried out in single organisations with no attempt at organisational comparisons and benchmarking. In addition, most of the researches have been theoretical exercises with no empirical data to back them up. Another gap described is the reactive and retrospective nature of most existing research, with no research aimed at developing a framework to predict future behaviour of the organisations. The final gap lies in the inability of existing research to show how to measure organisational reliability, or how organisations can improve or sustain their levels of mindfulness. The chapter introduced how the research intends to close these gaps, as well as the benefits of closing the gaps.

Furthermore, the chapter introduced the research methods and theoretical framework that informed the choice of the each research method. It also described the expected results and limitations of the research, the chief of which is the acknowledgement that research sample size may not be a true representation of all organisations in all industries, and as such the result might not be applicable across all industries and organisations despite the research's high confidence level. Secondly, the research acknowledged that although it purposely selected an organisation where the expected behaviour was expected to mirror a high reliability organisation, the result from it could potentially be different as it was not a traditional high reliability organisation.

Finally, the chapter reviewed some opportunities for future study, including a possible research that could seek to test how applicable the organisational reliability maturity model (ORM^2) and the framework for organisational reliability maturity (FORM) would be in traditional high reliability organisations. Such a research would either reinforce or dispel the myth of traditional high reliability organisations. In addition to high reliability organisations, a future research could also enhance the diversity and expand the study further into more industries and organisations with varying degrees of complexity, coupling, size, and age. This would help to further validate or debunk the standardization claims of this research.

The next chapter will discuss some literature related to this study and explain some concepts mentioned in this research. These would include reliability, mindfulness, disasters, high reliability organisations and maturity models.

CHAPTER TWO

Literature Review

2.1 Introduction

Chapter one introduced and outlined the background and rationale for the research. It identified two research questions*: "to what extent can the mindfulness of organisations be measured?"* and *"can these measurements help diverse organisations become more mature?"* It highlighted the aim and objectives of the research, as well as how each objective would help to answer the research questions. The chapter introduced some existing literature that supports the application of the high reliability theory to improve the maturity of organisations. It identified some gaps and highlighted how the research intends to fill the gaps. Chapter two will discuss the literature further and describe how they relate to the research, as well as how they will help to answer the research questions.

The chapter will begin with existing literature on disasters and what disasters mean with respect to the research. It will argue that most disasters are as a result of some actions and (or) inactions of individuals and organisations and as such could be avoided through series of reliability improving behaviours. It will present some case studies about disasters, the reports of which will support this argument and show retrospectively that the disasters could have been avoided through the adoption of certain behaviour by the people and organisations at the time.

The chapter will discuss the different perspectives about disasters and safety incidents and what constitutes the causative factors of incidents. It will show the similarities and contrasts between some of these perspectives and indicate which of the perspectives support the arguments of this research. Some of these perspectives will include the normal accident theory, the man-made disaster model, the energy barrier model, the conflicting objectives perspectives, resilient engineering, and the high reliability organisations theory.

The chapter will also discuss literature on mindfulness. It will argue on the premise that mindful organisations are learning organisations; and that the more the mindfulness and organisational learning culture, the more reliable the organisation, and consequently the less the probability of disasters. It will make a case for organisations to design processes that would help to create a culture of mindfulness and let that culture become part of their organisational genetic composition.

The chapter will furthermore discuss literature about the high reliability organisation theory and the different perspectives surrounding the theory. It will thereafter leverage on the works of Weick & Sutcliffe (2015), and describe the five principles of high reliability organisations. The chapter will end with literatures on maturity models and benchmarking. It will argue in favour of the usefulness of maturity models, and attempt to show how the maturity models would help in benchmarking and continuous organisational improvement. It will discuss the existing maturity models and how the maturity models fit into this research. It is hoped that this would set the stage for discussions surrounding the methods and methodologies adopted in conducting the research.

In this chapter, the words failure, incidents, near misses, accidents, and disasters would be used very often, and their definitions may vary in various contexts. For better clarity, it would therefore be appropriate to start with their definitions in the context of their use in this study. The next section shall define these terms

2.2 Definition of Terms

This section defines the key terms used in this research and the context in which they are used.

2.2.1 Failure

The British Standard (BS EN 13306:2010) defines a failure as the "*termination of the ability of an item to perform a required function"* It is the loss of a function under earlier defined conditions. Reason (2016) characterised failures as active and latent. Active failures are the losses of functions resulting from the actions or inactions of the responsible people with direct impact on processes, systems, or organisations. This could be in the form of slips, lapses, mistakes, errors, or violations by the responsible people in diverse job types. Job types could range from as pilots, manufacturing industry field operators, air traffic controllers, military, police officers, insurance brokers, safety supervisors, engineers, financial traders, maintenance personnel, and so many other types of personnel across diverse industries.

As shall be seen throughout this thesis, active failures, as characterised by Reason (2016), are not root causes, but merely consequences and symptoms. Latent failures on the hand define the root causes. They stem from lapses in organisational mindfulness as shall be discussed further in section 2.3. These could be in terms of inadequate procedure, gaps in communication, inadequate training, gaps in supervision, inadequate employee motivation, and inadequate tools and materials. They often arise from organisational decisions (or lack of), and may remain unnoticed for long periods until local factors and/or active failures combines with the latent conditions to cause a significant observable failure. Every aspect of a system or organisation has its failure mode(s): the way(s) the failure(s) could potential occur.

A failure mode and effect analysis FMEA (Labib, 2014) is a step-by-step approach for identifying all possible failure modes and the potential consequences of each failure mode. This is often combined with a criticality analysis to prioritize the severity of the consequences, their frequencies, and ease of detection. When combined, it is called a failure mode effect and criticality analysis FMECA. The focus of these analyses is to reduce failures to as low as reasonably practicable, starting with the potential failures with the highest priority in terms of severity, probability of occurrence and ease of detection. In some cases, the focus will not be to reduce or prevent failures, but to assure that potentials failures would not disrupt the process. This mind-set presupposes that failures could occur despite all best intentions to prevent it. The focus therefore centres on initiatives to ensure the potential failure do not lead to process failure, organisational failure, or catastrophe. This later mind-set forms the basis for reliability centred maintenance.

2.2.2 Incidents and Near Misses

The British Standard (BS 11200: 2014) defines an incident as *"an adverse event that might cause disruption, loss or emergency, but which does not meet the organisation's criteria for, or definition of, a crisis"*. An *incident* therefore is an unexpected, undesired, and retrospectively avoidable event that causes, or has the potential to cause interruption of processes or tasks; injury, illness or fatality to a person or people; physical or virtual asset damage; environmental pollution; or negative financial or reputational impact. The key here is retrospective prevention: if all appropriate actions that led to the incident were taken, the incident might not have happened. Where the incidents lead to negative consequences, those consequences are referred to in this research as *top events*. This is in contrast with an *accident*, which presupposes that in retrospect, the event could still have happened despite the human or organisational actions to prevent the occurrence.

A *near miss* on the other hand is an incident that did not result in any top event. The Institution of Engineering and Technology glossary of safety terminology (IET 2017) defines a near miss as "*an incident, which did not show a visible result, but had the potential to do so".* The focus on near misses is the potential to result in a top event. It is sometimes referred to as a *close call* or *near hit.* As will be show in section 3.7.3: assessing preoccupation with failure, research has shown a relationship between near misses and actual top events. Frank Bird (Morrish, 2017) demonstrated from a study of more than one million incidents, that every incident that involves asset damage is usually preceded by about twenty near misses. His research also shows that for every one serious injury or fatality, there would have been about ten minor injuries, 30 asset damage, and 600 near misses. This is described in more details in section 3.7.3. Near misses therefore are early warning signs about the state of processes, systems, or organisations.

The UK Airprox Board (Airproxboard, 2017) collects near miss data from all flights within the UK airspace. Near miss in their instance is a situation in which, in the opinion of the pilot or air traffic services personnel, the safety of the aircraft, in terms of distance, speed, and relative position, may have been compromised, but with no obvious harm to the aircraft, passengers, or crew. Their 2015 showed that 217 near misses with 49% of them categorized as Risk category A and B. The risk categories range from A to E with A being the most severe near miss and E the least severe. Category A near misses are the serious incidents where serious risk of collision existed, and where collision avoidance was only left to chance. Categories B near misses are the major incidents where serious risk of collision existed, and where collision avoidance was as a result of a last minute but timely intervention. Category C near misses are significant incidents where there were no risks of collision due to early effective and timely actions. Categories D and E are the least serious incidents. The near misses are often the risk of collision with flying objects such as balloons, drones, and birds. The organisation mindfully records and analyses all these near misses with the view to understanding the pattern and preventing collisions. Their ten year report below indicates an increasing number of near misses in the last few years, the investigation of which showed the increase was as a result of increasing drone activities. 6 near misses in 2014 were as a result of drone activities, against 29 of such in 2015, all of which were either category A or category B. This report, in conjunction with other similar reports, has led to the establishment of the CAA Skyway Code (CAA, 2017) that regulates the use of airspace. Recording and analysing near misses are therefore key to disaster prevention and management, and organisational improvement.

Table 2.1 – 10-Year Airprox notifications and risk assessment statistics showing the near misses recorded over the last 10 years. Adapted from Airproxboard.org.uk

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	10-year Average
Category A	15	9	13	11	12	23	18	22	28	41	19
Category B	40	39	38	36	33	36	27	43	68	66	43
Category C	103	106	100	97	116	88	97	72	86	78	94
Category D	1	0	4	3	6	2	5	9	9	12	6
Category E						12	14	26	33	20	21
Annual Totals	159	154	155	147	167	161	161	172	224	217	217
Risk Bearing	35%	31%	33%	32%	27%	37%	28%	38%	43%	49%	36%

In summary, consider a slippery stair at home resulting from a water tap that was mistakenly left running. The owner rushes in to quickly pick up something, routinely assuming to know every inch of the house, takes the stairs 2 steps at time, slips and falls, with severe injuries. This event is an incident, and the severe injury is the top event. Suppose the owner, just before falling, grabs the rails; or just before taking the flight of stairs gets a phone call and stops. This becomes a near miss as the potential for a top event was there.

2.2.3 Emergency, Crisis and Disaster

The words *emergency, crisis,* and *disasters* are often interchangeably misused and their meanings as used in this research are therefore highlighted here. Borodzicz (2005) defined emergencies as "*situations requiring a rapid and highly structured response where the risks for critical decision makers can, to a relative degree, be defined".* Emergencies are basic potentially disruptive events that individuals or organisations could plan for and provide known and predefined responses to minimize or prevent injuries, fatalities, asset damage, financial loss or reputational loss. If emergences are not well managed, they could result in *crises*. A *crisis* on the other hand is a "*global, regional or local natural or human-caused event or business interruption that runs the risk of intensifying or causing damage to an organisation not only financially but also with its reputation"(*ASIS, 2005). This definition is closely related to the British Standard's (BS 11200: 2014) definition of crisis as *"abnormal and unstable situation that threatens the organisation's strategic objectives, reputation or viability"* It is worthy to note at this point that both definitions refer to a crisis as a threat to the organisation. If this threat is not managed correctly, it could easily become a disaster.

A d*isaster* is an event, both retrospectively preventable or not, that "*inflicts widespread destruction and distress"* (Labib, 2014). They are sudden unforeseen events with natural, technological, or social causes that lead to destruction, loss and damage (Al-Dahash et al, 2016). It is usually a resultant effect of a poorly handled emergency or crisis. Labib & Read (2015) considered disasters as black swans with the distinct attributes of rarity, extreme impact, and retrospective predictability. Taleb (2010) had defined a black swan as an event that lies outside the realm of normal expectations, but carries extreme impact when it does occur. Disasters could be natural or man-made, and the occurrence, like a black swan, would always lead to a scramble for retrospective explanations with the outcome that the event could seem predictable. This research runs on a common theme that disasters could be prevented, or its effects minimized through the mindfulness behaviours of organisations. As would be shown in later sections, even natural disasters are actually "man-made" disasters and could therefore be prevented or its effects minimized through acts of organisational mindfulness. The next section shall discus the principle of mindfulness and its context as it applies to this research.

2.3 Principle of Mindfulness

The principle of mindfulness progressed from Buddhism, an Eastern religion that suggests means of enhancing attentional stability and clarity, and of then using these abilities in the introspective examination of conscious states to pursue the fundamental issues concerning consciousness itself (Weick & Putnam, 2006). To the practitioners of Buddhism, mindfulness is built on the foundations of introspective awareness of the body, feelings, consciousness, and mental objects and focuses on mental discipline. It means having the ability to focus; to hang onto current objects; remember them; and not lose sight of them through distraction, wandering attention, associative thinking, explaining away or rejection (Weick & Putnam, 2006).

Mindfulness becomes fully developed when the three qualities of "*impermanence*", "*unsatisfactoriness*", and "*selflessness*" becomes an ongoing awareness. Impermanence refers to the feeling that things are changing or slowly dissolving, especially when concepts related with positive mental fabrications have been accepted, concepts associated with negative feeling tones rejected and concepts associated with neutral feelings ignored. When people become attached to impermanent things, negative changes to those things would lead to unsatisfactoriness: a sense of fearfulness leading to suffering (Weick & Putnam, 2006). Selflessness on the other hand refers to the nonexistence of an unchanging self: a gap between reality and the individual awareness of that reality.

Recent researchers consider the Buddhist perspective on mindfulness as being negative: a focus that Langer (2000) referred to as being on mindlessness rather than on mindfulness. To her, mindfulness should be studied from the perspective of a flexible state of mind in which people are actively engaged in the present, noticing new things, and being sensitive to the context of things. People do not act mindfully when they rely on past categories and get fixated on long held perspectives irrespective of the changes taking place around them. She advocates stirring the cognitive pot instead of engaging in a quiet meditation. The resultant disruptions would induce some moments of concept free mindfulness. People would become more sensitive to their environments, become more open to new information, create new categories for structuring perception, and there would be an enhanced awareness of multiple perspectives in problem solving (Weick & Putnam, 2006). Taylor & Millear (2016), citing Brown & Ryan (2003), described mindful individuals as individuals that perceive their internal thoughts and external sensations without attempting to avoid them, or mentally labelling them as 'good' or 'bad'. It is a particular state of consciousness, one in which the individual focuses on present moment events (Sutcliffe et al, 2016). The individual understands the present moment events and their implications and interrelationships with other events around. Langer (2014) expands this further by defining mindfulness as "*an active state of mind characterized by novel distinction drawing that results in being (1) situated in the present, (2) sensitive to context and perspectives, (3) guided (but not governed) by rules and routines*". Sutcliffe et al (2016) calls this collective mindfulness or organisational mindfulness.

Mindfulness within the organisational context refers to the ability of an organisation to be aware of and to understand the context of the current situational realities, the relationships between current realities and expected objectives, and is able to act collectively in ways that safeguards and enhances its long term goals. Weick & Sutcliffe (2007) described mindfulness as a rich awareness of discriminatory detail – a big picture view that is situationally aware, continuously scrutinizing, differentiating and refining expectations based on newer experiences. To them, mindful organisations are consistently concerned about the quality of their attention, and are conscious of the potential vulnerability to error occasioned by distracted and unstable attention, dominated by abstractions.

Organisational mindfulness is concerned with a focus on a 'clear and detailed comprehension of emerging threats, and on factors that interfere with such comprehension' (Weick & Sutcliffe, 2007). It results in early failure detection, and avoids the fallacy of hasty generalization and oversimplification. Mindfulness ensures everyone works collectively with a common purpose, and with clear communication among staff and between staff and management. It ensures everyone is aware of operational requirements and is collectively committed to early detection and cascade of symptoms of failure. Should a failure occur, a mindful organisation works collectively to recover from it and progress to the next stage of its evolution. The principle of mindfulness is therefore the key to keeping the organisation focussed on what really matters based on current situational realities, and it prevents the ‘mind’ of the organisation from ‘wandering off’. It is the key to preventing catastrophic accidents and helping organisations to remain resilient should disasters occur. Organisational mindfulness comprises of five interrelated behaviours at multiple organisational levels. These are preoccupation with failure, reluctance to simplify, sensitivity to operations, commitment to resilience, and deference to expertise (Sutcliffe et al., 2016; Weick & Sutcliffe 2001, 2007, 2015; Weick et al., 1999). The first three deal with the ability of organisations to avoid failures, while the last two deal with the ability of the organisation to withstand the negative effects of failure when they occur. Preoccupation with failure is an active consideration and ongoing wariness of the potential for failure (Sutcliffe et al., 2016). Reluctance to simplify questions received wisdoms and assumptions and encourages scepticism avoid oversimplification and uncover blind spots. Sensitivity to operations is an active consideration of current operating parameters and indications and the integrated understanding of their relationships with interconnected processes. A commitment to resilience involves developing the organisational capacity to adapt, improvise and recover from unexpected events, and be able to learn from the experience. Finally deference to expertise occurs when the most experienced people are empowered to take decision and solve problems irrespective of hierarchical positions within the organisation (Weick & Sutcliffe 2001, 2007, 2015).

Awareness of the moment means that organisations with mindfulness continuously learn from themselves and from others. A mindful organisation is a learning organisation. The next section shall discus organisational learning in the context of this research and shall highlight its relationship with organisational mindfulness.

2.4 Principle of Organisational Learning

Learning is the process of acquiring new or modifying existing knowledge, behaviours, skills, values, or preferences (Gross, 2015). Research into organisational learning has evolved over the years and a general consensus on a concise definition been difficult to achieve, primarily due to the multidisciplinary nature of organisational learning (Saadat & Saadat, 2016). Marquardt (2011) and Crossan et al (1999) studied organisational learning from the perspective of organisational continuous improvement. Mayo (1994) viewed organisational learning from the perspective of the methods, mechanisms and processes used by organisations to achieve learning. Argyris (1977) and Alvani (2008) viewed organisational learning as the process of discovering and correcting errors and mistakes. In all these perspectives, one concept was common: the that applying the process of creating or acquiring new or modifying existing knowledge, behaviours, skills, values, or preferences; retaining the knowledge; and transferring the knowledge among the components of an organisation; forms the background of organisational learning.

An organisation could learn from itself, from others, or a combination of both. It occurs at different levels of an organisation: organisational, sectional, group and individual levels (Saadat & Saadat, 2016). Marquardt (2002) grouped organisational learning into adaptive, forward looking, and practical learning. Adaptive learning happens when an individual, a group or an organisation learns through experience and evaluation of previous experiences. Forward looking learning occurs when the organisation learns through the identification of prospective future opportunities and explores ways to achieve them. Practical learning consists on working on real issues and actual performance of solutions (Saadat & Saadat, 2016). Dawes (2003) classified organisational learning in terms of hereditary learning, experimental learning, and vicarious learning. To him, hereditary learning is handed down by the founders of the organisation, while experimental learning is obtained through first-hand experience of the organisation and the social actors within the organisation. Vicarious learning on the hand is obtained through the second-hand experience of others in the organisation or outside the organisation, but has been adopted for learning.

Argyris and Schon (Lukic et al, 2012) studied organisational learning from the perspective of behavioural psychology and organisational development. They described learning as comprising of two modes: the single-loop learning and the double-loop learning. In single-loop learning, the organisation corrects a mistake by adopting a different strategy or method that is expected to yield a different result to achieve the set goal. The organisation would reflect on the mistake and develop learning from mistake that would recommend different sets of actions to achieve the same goal. This often considered a "quick fix" approach. The double-loop approach on the other hand considers the process of rethinking the initial goal to change the organisational factors and that often cause incidents. It is based on open inquiry into deep rooted causes, system failures and organisational values, and questions the underlying assumptions of organisational work (Lukic et al, 2012). In single-loop organisational learning, the organisation identifies a mistake, analyses the mistake, takes corrections and proceeds with existing goals and policies. In double-loop organisational learning, the organisation identifies a mistake, analyses the mistake, analyses its goals and policies, and changes the goals and policies before implementing corrective actions.

As the organisation continues to perform improvement actions it accumulates experience which becomes embedded within the organisation. These experiences become the repositories for organisational learning. These repositories could be in the form of explicit or tacit knowledge (Virtanen, 2015). Explicit knowledge includes the processes, procedures, standards, and instructions that the organisations would develop and enforce. It is declarative, factual and relatively easy to transfer through written verbal or codified media. Tacit knowledge on the other hand is not easily documented, and as such is not shared simply through verbal and written communication modes. It includes the behaviours learned through experience over time. It is mostly achieved through on-the-job learning, coaching, and continuous practice. Lukic et al (2012) further classified knowledge into four: conceptual, procedural, dispositional, and locomotive. To them, conceptual knowledge is concerned with the knowledge of the "facts, concepts, information and propositions"; as well as the knowledge of what things are, and why things operate the way they do. Procedural knowledge on the other hand is concerned with the knowledge of “how”: the techniques and skills that enable the development of conceptual knowledge. Locomotive knowledge helps identify the locations and sources of relevant knowledge. This is acquired through networking, interactions, and trainings. Finally dispositional knowledge consists of attitudes, values, emotions, interests and personal motivations that support the development of all the other knowledge types. These are the mindfulness behaviours that drive the organisation.

Mindfulness is a key component of organisational learning. As stated earlier, mindfulness requires a “clear and detailed comprehension of emerging threats and on factors that interfere with such comprehension’ (Weick & Sutcliffe, 2007). It also requires the ability the organisation to be resilient and react to unexpected threats and changes. For this rapid response to happen, then a degree of deliberative computation must be taking place. In reality, no classical cognitive process of representation or deliberative calculation is taking place. Levinthal & Rerup (2006) suggests the response to be as a result of one or a combination of an existing repertoire of initiatives available to the organisation, and a possible recombination of existing routines. The actors within the organisations are able to choose or combine solution from an inventory of established routines. The inventory of established routines must first be developed in form of explicit or tacit knowledge. A ball player instinctively and instantaneously uses a variety of skills within his repertoire to perform on the field, either when defending, attacking, or just entertaining. These mindfulness behaviours must first be developed and are indeed developed over the years. He reads instruction manuals and watches instructional materials (explicit knowledge). He also listens to coaches, learns from team mates and continuously practices (tacit knowledge). All these together help to build the repertoire of skills he would require to perform mindfully at top level on the field. In a similar manner, organisational mindfulness would require a combination explicit and tacit knowledge to build the repertoire of initiatives required by the organisation to be aware of and to understand the context of its current situational realities, and act to safeguards and enhances its long term goals. A mindful organisation therefore has organisational learning embedded at its core. In organising for mindfulness, the organisation would utilize existing prototypes from its repertoire as foundations to develop new processes, procedures and solutions to current problems. The organisation recognises patterns and dips from its repertoire of existing knowledge to link the patterns with possible sets of solutions. According to Levinthal & Rerup (2006), mindfulness in action is local and situated and involves spontaneous recombination of knowledge from existing organisational repertoires. It is therefore safe to say that a mindful organisation is a learning organisation.

Mindful organisations learn from their successes, as well as from their failures. According to the attribution theory (Ross & Nisbett, 1991; Gilbert & Malone, 1995), there is always the tendency to neglect the roles of the actions of internal forces in failures, and instead attribute the failures to external factors; while attributing the successes to the internal forces. Mindful organisations understand the negative impact of attribution on incidents and therefore take proactive steps to achieve learning root cause analyses of successes and failures. They not only learn from their own experiences, but also from the incidents and experiences of others (Huber, 1991; Kim & Miner, 2007). According to the behavioural theory of the firm, organisations learn differently from successes and failures. A failure is often perceived as an indication of a flawed process and an incorrectness or inappropriateness of existing assumptions (Sitkin, 1992). The organisation therefore mostly begins a number of learning from failure or learning from incident initiatives.

Effective learning from incidents is critical to safety (Lukic et al, 2012) as it allows the knowledge to be applied and embedded in work environments to prevent future incidents (Littlejohn et al, 2017). This research hopes to help organisations tend towards more mindfulness. This means they will become more aware of their current realities and inter-dependencies between their current realities and the situations around them. It also means that they will begin to create knowledge and utilize the knowledge towards organisational learning; they will begin to adopt learning from successes and learning from incidents strategies.

It is one thing to create knowledge, and another to retain the knowledge. An organisation could easily jump from organisational learning to organisational forgetting through a succession of unchecked behaviours. Knowledge retention could be achieved through the use of people as repositories. As people gain experience and improve their mindfulness behaviours, they are expected to transfer the knowledge. This potentially poses some challenges as the viability of people as repositories is highly limited. Attrition, layoff, retirements, ineffective motivation, and individual inability to transfer knowledge could potentially increase the vulnerability of organisations to knowledge retention. Organising for mindfulness therefore considers the knowledge creation, retention and utilisation holistically through its preoccupation with failure, reluctance to simplify, sensitivity to operations, commitment to resilience, and deference to expertise. These mindfulness behaviours form the foundation for the high reliability organisation theory that has helped organisations develop and sustain high performances in reliability and safety. This shall be discussed further in the next section, but to understand this concept, and why this concept is important to this research, the next section shall begin with the description of the different perspectives on incident causation. It will thereafter describe the high reliability organisation theory and as well as justify why this theory was selected above others for this research.

2.5 Perspectives on Safety Incidents and Causative Factors

2.5.1 Introduction

Over the years, researchers have tried to identify the causative factors of incidents and disasters with a view to preventing catastrophes, saving lives, preserving assets, organisations, and the environment. Different researchers have arrived at different conclusions and propounded different theories, with different perspectives on the causes and prevention of these incidents. Some of the perspectives have included the normal accident theory, the black swan theory, inherent safety, defence-in-depth model, the high reliability organisation theory, the man-made disaster model, energy barrier models, the conflicting objectives theory, and resilient engineering. Some of these will be discussed below. The aim is that by understanding causative factors, this research could identify commonalities that would guide it towards the development of a reliability improvement framework.

2.5.2 Normal Accident Theory

Perrow (1984) proposed the Normal Accident Theory, which presupposes the inevitability of accidents in complex organisations where high risk technologies are deployed. He proposed this theory following the Three Mile Island accident of 1979 in Pennsylvania, where a nuclear power plant had a meltdown (Saleh et al, 2010; 2012). He argued that no matter how well a system is managed, accidents are inevitable, as long as the system is characterised by complexity and tight coupling. Whereas coupling refers to the degree of interdependence among the components of a system such as the people, materials, equipment, procedures, for example in highly automated systems; complexity on the other hand refers to the degree of unpredictability and invincibility of the interactions between the components of the system. Since the systems are coupled, he argued, a failure in one part is quickly translated to other parts, creating an avalanche reaction that could lead to catastrophe. To him, the Three Mile Island incident was "*unexpected, incomprehensible, uncontrollable, and unavoidable: such accidents had occurred before in nuclear plants, and would occur again, regardless of how well they are run"* (Saleh et al, 2010; 2012).

Most researchers consider this theory as defeatist and pessimistic as it does not give room for continuous improvement (Saleh et al, 2010; Kim et al, 2016). Perrow agreed in another work (1994) that personnel negligence and incompetence is a major causative factor of major accidents, but argued that these human incompetence and negligence should be expected given pressures imposed on the system directly or indirectly by the management, production, and market forces. This theory appears defeatist and does not identify how to prevent accidents in complex systems, which can only get more complex given the rapidity of today's technological advancement. In his review of petrochemical accidents, Perrow seemed to gradually veer away from the normal accident theory by asserting that organisational ineptitude, inadequate skill levels, inability to get expert advice, inadequate supervision, and strong production pressures were the major causes of industrial accidents (Perrow, 1994; Hopkins, 2014)

Perrow's perspectives may have been heavily influenced by his background in Sociology as he tried to shift the blames away from the operators, who were mostly blamed for most industrial incidents. It showed gross oversimplification or lack of understanding of engineering and technological processes and operations. Its critics leverage on its pessimism and its lack of contributions to stakeholder decisions in design and operation of processes. The next perspective, the Turner's made-made disaster model, also takes a sociological perspective, but veers away from the inevitability of these events.

2.5.3 Turner’s Man-made Disaster Model

Turner’s man-made disaster model (Turner, 1978; Turner, 1994; Turner & Pidgeon, 1997; Pidgeon & O’Leary, 2000; Rousness et al, 2010; Kim et al, 2016) argues that disasters and major incidents are results of series of actions and inactions of individuals and organisations. It proposes that disasters would always develop through a long chain of events that leads back to root causes such as lack of information flow and misperception among individuals. Turner’s man-made disaster model traces typical catastrophic events back to initial beliefs and norms that run contrary to existing regulations. This would normally happen over time – “*the incubation period”* – a period where these discrepancies would quietly develop and accumulate. Actions taken within this period may lead to a “*decoy phenomena” (*Turner 1978), a condition where the perceived solution to the perceived problem would retrospectively be found to have distracted attention from the real causative factors.

Turner (1987) described six stages that he believed disasters progress through. It starts with the “*notionally normal starting point”*, a stage characterized by culturally accepted beliefs about the world and hazards, as well as precautionary norms in laws, codes of practice, or traditional folkways. The second stage is the “*incubation period*”, a period characterized by the accumulation of unnoticed events that contradicts the notionally normal starting points. The third stage is the *“precipitating event”*, a period where the general perceptions are transformed, and the norms, cultures, and beliefs are disrupted. The fourth stage is the “onset”, a stage in which the consequences become obvious. The fifth stage is the “*rescue and salvage”*, a stage characterized by people scrambling to deal with the immediate problems. The final stage is the “*full cultural readjustment”*, a stage characterized by investigations and lessons learned. Here, the beliefs and cultures are adjusted in line with the lessons learned from the incident.

The man-made disaster model asserts that in every industrial incident, there would always be some level of culpability by someone within the organisation, who has some knowledge of the hazardous circumstances leading to that disaster, but fails to take action; or whose action would be ignored by the organisation leading to the disasters.

Such errors could either be of Type 1 or Type 2. Type 1 errors occur when the personnel or the organisation rejects the correct interpretation of the events, cues or triggers leading to the disaster; while type 2 errors occur when the individual or organisation accepts a false interpretation of those events, cues, or triggers. In both cases, there is a misrepresentation of the facts. In some cases, there could be a correct representation and interpretation of the events, cues, or triggers, but the response required to mitigate the problem could be faulty. Additionally, the disaster could be as a result of type 3 errors, where the strategies designed to reduce the risk actually exacerbates it. In all cases, according to Turner's model, the incidents would be a resultant effect of the actions or inactions of individuals and organisations.

2.5.4 Inherently Safer Design Model

Most conventional safety systems enhance safety by reducing potential hazards through the use of additional safety features. These additional safety features mostly provide additional safety layers to limit the interactions between the hazard and the people, organisation, environment, and assets (see section 2.5.6). Risk reduction in conventional safety systems is achieved by the reduction of the potential likelihood of incident occurrence, or by the reduction of the magnitude of impact. Bollinger et al (1996) and Hendershot (1998) described four strategies aimed at risk reduction: inherent, passive, active, and procedural strategies. According to Khan & Amyotte (2003) inherent strategies involve the use of less hazardous materials and process conditions, while passive strategies involve the reduction of either incident frequencies or consequences without the active functioning of devices. Active strategies on the other hand involve the use of engineered features such as controls, and shutdown systems to detect, control or mitigate potentially hazardous conditions. Procedural strategies use management and administrative approaches to prevent incidents or minimize their effects.

Inherently safer design methods leverage on the inherent strategies to develop designs that model the properties of the system or process, rather than the timely operation or intervention of the devices or people tasked with the responsibility. The model works on the premise that the conventional safety techniques cannot reduce or eliminate the conditions that creates the hazards (Pasha et al, 2017; Khan & Amyotte, 2003). The inherently safer design therefore concentrates effort to reduce or eliminate the hazard. According to the concept originator Trevor Kletz (1978), *"what you don't have, can't leak",* which translates that if the hazards are not there in the first instance, there will be no need to deploy additional safety layers to control them or mitigate their effects. Inherently safer designs therefore avoid hazards instead of controlling them; they are inherently "*safer"*, not inherently *"safe"* as the hazards may not be realistically completely removed (Kletz & Amyotte, 2010).

Hendershoot (1999) and Khan & Amyotte (2003) summarized the basic principles behind the inherently safer design model in four basic building blocks. These are to minimize, to substitute, to moderate, and to simplify.

Minimize: This principle involves the reduction of the amounts of hazardous conditions or materials present at any given time. This could be through inventory reduction, increased efficiency of processes and process equipment, and reduced or reused process bye products

Substitute: This involves the replacement of materials, processes, and systems with less hazardous ones. For instance, flammable solvents used as cleaning agents could be replaced with water based and less hazardous cleaning agents.

Moderate: Kletz (1978) had originally used the term *intensification* to describe this principle. It involves the reduction in the strength of an effect through the use of less hazardous conditions or less hazardous forms of a material. It could also be through the use of facilities that minimize the impact of a release of hazardous conditions or materials. An example would be the use of cold liquid in place of pressurized gas in a manufacturing process. Other examples are the use of diluted solutions in place of more concentrated ones; and the refrigeration of volatile hazardous substances.

Simplify: Kletz (1978) had used the term *attenuation* to describe this principle. It involves the elimination of potential safety issues through design instead of dealing with the issues through the addition of additional equipment or features. The design is such that unnecessary complexity is eliminated, making operating errors less likely.

Inherent safety has been described as *common sense design* (Edwards, 2005). In simple terms, bungalows are inherently safer than two-storey buildings due to the absence of stairs, considered a major hazard in homes. The stairs are made safer by the addition of extra safety features such as handrails, less slippery surfaces, and lighting. Designing a home without stairs therefore makes the home inherently safer.

2.5.5 Defence-in-depth Model

The target of the defence in depth safety model is to protect both the workers and the public from the consequences of process failures. It is used widely in the nuclear industry. In nuclear power plants, "*all safety activities, whether organisational, behavioural, or equipment related are subject to layers of overlapping provisions, so that if a failure should occur it would be compensated for or corrected without causing harm to individuals or the public at large. This idea of multiple levels of protection is the central feature of defence in depth..."* (INSAG-10, 1996). Defence in depth in its simplest form involves the design and implementation of multiple safety barriers: technical, procedural, and organisational; with the objective to prevent incidents, or block the incident sequences from escalating, or to mitigate the adverse effects of the incidents should the first two barriers fail (Favaro & Saleh, 2014).

Different organisations deploy different levels of barriers to suit their process. The International Nuclear Safety Advisory Group (INSAG-10) generally structured defence in depth in five hierarchical levels of deployment such that one level activates as soon as the preceding barrier level fails. The first level prevents abnormal operations and system failures. If the first level fails, the abnormal operation is detected by the second level and controlled. Level two seeks to control the abnormal operation and detect failures. Its functions include controlling, limiting and surveillance of the systems. The third level activates specific safety systems and other safety features to ensure that safety functions are further performed and the abnormal operation brought under control, in the event of failure of the second level. Should the third level fail, the fourth level: an incident management process that seeks to limits the progression of the incident is activated. The objective of level four is to control severe plant conditions, including the prevention of incident progression and mitigation of the consequences of the severe accidents. The fifth and final level is the off-site emergency response process that is activated should the fourth level fail. These progression levels are geared towards ensuring that the hazardous situations or substances are contained, and does not propagate to the workers or to the public.

Defence in depth compensates for uncertainties, inadequacies or incompleteness in risk analysis and protects the assets, the employees, and the public from hazardous consequences of process failures (Favaro & Saleh, 2014). Despite its obvious usefulness in incident prevention and mitigation, defence in depth has been criticized for some of its drawbacks (Favaro & Saleh, 2015). The multiple layers of barriers may hide from the operator, a potentially hazardous situation that are currently occurring, but is being mitigated by one of the levels. The operator might be blindsided with a false sense of safety, despite the fact that the level three might have been activated, thereby shortening the operator's intervention or response time. According to Favaro & Saleh (2014), "*defence-in-depth may create safety blind spots and decrease situational awareness, which in turn (*could) *translate into a shrinking of the time window available for operators and decision-makers to identify an unfolding hazardous condition or situation and intervene to abate it"*

Despite this drawback, highly hazardous industries such as the nuclear industry have adopted this model in one form or another. They consistently refine the process as new threats are discovered.

2.5.6 Energy-Barrier Model

The energy barrier model seeks to understand the sources of the energies that create hazardous conditions within a process; the routes those energy sources can escalate to a top event; and the potential means by such escalations could be prevented or mitigated. Haddon (1970, 1980) popularized the energy and barrier perspective. He identified 10 rules to help avoid, control, and mitigate incidents, and grouped them into 3: energy source, barrier, and vulnerable target (Table 2.2).

Table 2.2 – Energy and Barrier Model showing the 10 energy barrier rules arranged in three groups. Adapted from Haddon (1980)

Energy Source	**Barrier**	**Vulnerable Target**
Prevent build-up of energy	Separate in space and time, the victims from the energy being released	Make the vulnerable target more resistant to damage from the energy flow
Reduce the amount of energy		
Prevent uncontrolled release of energy		
energy	Separate the victims from the energy by physical barriers	Limit the development of damage
Modify the qualities of the energy		Rehabilitate the victims

The more to the left the efforts are concentrated, the higher the likelihood of incident prevention. The efforts on the right hand side are mostly mitigation factors, or factors to protect the target from potential impact. The barriers are the physical (hardware barriers) and non-physical (software barriers) means designed to prevent, control, or mitigate incidents. The hardware barriers are the equipment, including humans, while the software barriers include the processes, procedures, and routines required to implement the barrier functions under specific conditions (Rossness et al 2010). Sklet (2006) and Kim et al (2016) further classified barriers into barrier systems or barrier functions. According to them, a barrier function is ‘‘a function planned to prevent, control, or mitigate undesired events or accidents”, while a barrier system is ‘‘a system that has been designed and implemented to perform one or more barrier functions”. Taking a functional view is useful as it helps to focus attention on activities that are necessary to control or mitigate a specific hazard. It also helps users to consider alternative scenarios in case of a failure of the barrier.

The energy barrier model could be likened to the tiger in a cage. As long as the cage (hardware barrier) is secure, and the safe process of feeding and caring for the tiger (software barriers) are adhered to, the tiger (the energy source) will not harm the people around (vulnerable target). Optimizing the number and quality of barriers is one method to reduce the probability of hazard escalation. In the Swiss cheese model (Reason, 2016), each barrier is expected to have holes: potential flaws through which the energy source might be released. Focus will therefore be on "*defence-in-depth":* increasing and optimizing the quality and quantity of barriers so that the holes do not align to cause catastrophic events. Figure 2.1 shows the Swiss cheese model with four barriers. Each barrier (slice of cheese) has holes, and the holes have aligned to allow the hazard to be released.

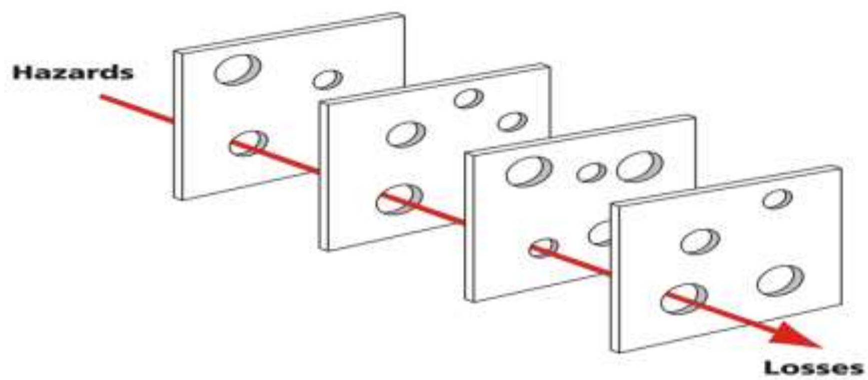


Figure 2.1 – Swiss cheese model showing the alignment of holes to release the hazard. Illustration by Davidmack licensed under CC BY-SA 3.0

The energy-barrier model is exemplified by the bow-tie risk model (Figure 2.2). On the left hand side are the preventive barriers that work to ensure the incidents do not occur. When the holes align, the incidents will occur as shown in the middle part of the bow tie. Latent failures could occur within the barriers but as long as the holes do not align, there will be no catastrophic event. A mindful organisation will have a process in place to monitor the barriers for latent failures and rectify the failures before or as soon as they occur. The right hand side shows the mitigation barriers: recovery barriers put in place to mitigate the incident, or to protect the intended targets from the harmful effects of the incidents. All the disasters discussed in section 2.6 were either as a result of the alignment of holes within the barriers, or the use of inadequate barriers (a hole within the management process itself). Better results would be obtained when the right combination of hardware and software barriers are used.

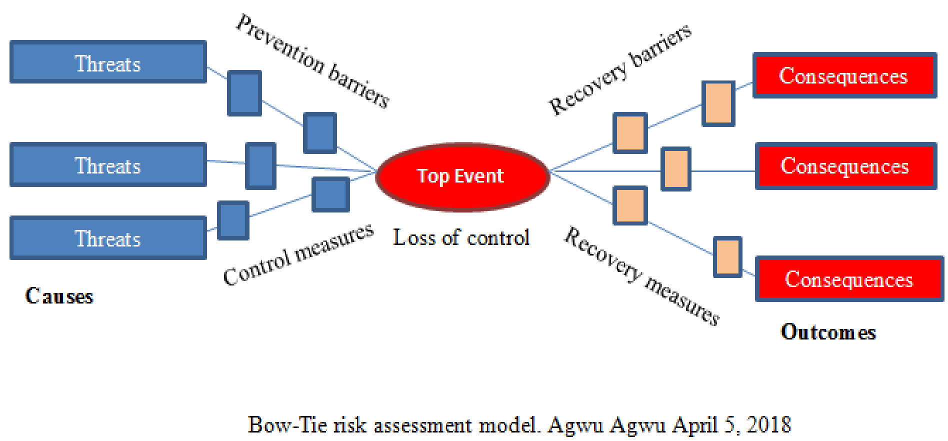


Figure 2.2 – Bow-Tie energy risk assessment model showing the prevention barriers, the top events, and recovery barriers.

2.5.7 Conflicting Objectives Perspective

With increasing pressure from stakeholders, including business owners, governments, regulators, the press, host communities, non-governmental organisations, and so many others, individuals and organisations are exposed to conflicting organisational priorities: profits, cost savings, production increase, safety, diversity and inclusiveness, environmental protection, reputation, and so many others. A production manager in one of the researcher's previous organisation once tried to seek clarifications if his organisation was an oil company interested in safety or a safety company interested in oil. According to Rasmussen (1994; 1997) and Kim et al (2016), such confusion in parallel objectives has the potential to change the boundary of acceptable risk in one of the competing objectives, creating a hazardous situation. The Bhopal disaster (Section 2.6.3) clearly demonstrates the conflicting objectives perspective. Union Carbide continued operations despite the attrition rate that depleted their experienced personnel. They did not update their designs in line with international industry standards, and allowed their safety processes to be downgraded. The authorities were informed of the possibility of an incident given the organisation's operating conditions, but they needed to keep people employed, as well as the community and government revenues intact. The conflicting objectives were quality, safety, revenue, keeping the jobs, and public image. Their choice to keep production despite all warnings and indications to failure resulted to the one of the world's worst industrial disasters.

The conflicting objective perspective is especially pronounced in complex systems where many concurrent activities take place. This would be characterized by distributed decision making due in part to the incomplete or inaccurate instantaneous knowledge about the process by the actors in each concurrent operation; and the interactions between the concurrent operations (Rasmussen 1997; Rousness et al, 2010; Kim, 2016). Decisions in one concurrent operation may therefore change the boundaries of acceptable performance in another operation (Figure 2.3).

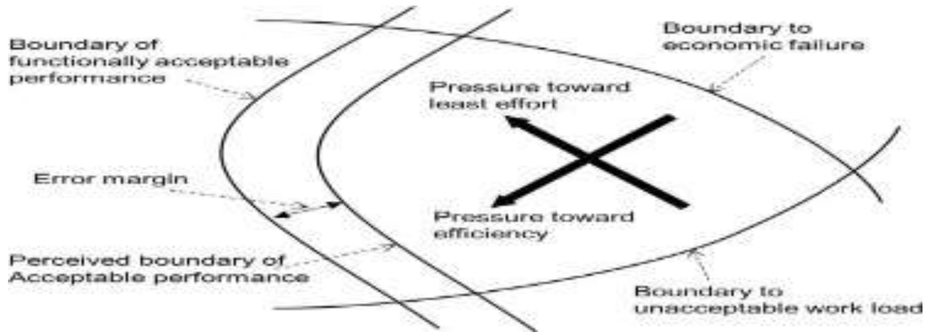


Figure 2.3 - The Migration Model showing changes in the boundaries of acceptable performance. Adapted from Rasmussen, 1994

Organisations develop administrative process such as permit to work system and various enterprise resource management processes to combat the effects of distributed decision making on conflicting objectives. These could still however fail, as in the case of Piper Alpha incident (Section 2.6.6), resulting in catastrophic incidents.

In addition to conflicting objectives based on concurrent operations, levels of decision making could result in conflicting objectives. The employee on the shop floor may have a different perspective from the manager. The chief financial executive would be interested in the return on investment, the production manager on the production figures, while the chief safety officer would be in interested in enhancing personal and process safety. These objectives would often conflict. Finally, the different stakeholders may also have conflicting perspectives. Whereas the business owner maybe interested in revenues, the regulators, the government, the host communities, and the investors may all have different and often conflicting objectives. The ability to manage these conflicting objectives is key in keeping organisations safe from disasters.

2.5.8 Resilient Engineering

The seventh perspective about disasters to be discussed is Resilient Engineering. Foster (1993) defined *resilience* as "*an ability to accommodate change without catastrophic failure, or a capacity to absorb shocks gracefully*". It suggests elasticity – an ability to withstand stress and return to original state. It comes from the Latin word "*resilire",* meaning "to leap back" and denotes a system property characterized by an ability to recover from challenges or disrupting events (Woods, 2006). Resilience is an endowed or enriched property of a system that is capable of effectively combating (absorbing, adapting to or rapidly recovery from) disruptive events (Francis & Bekera, 2014). The concept of resilience is viewed from different perspectives by different disciplines.

Francis & Bekera (2014) discussed the various perspectives of resilience viewed from the lens of different subject areas. In infrastructure systems, resilience is viewed as "*an ability to reduce the magnitude and/or duration of disruptive events"*. It is the ability of the resilient infrastructure to *"anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event"*, and "*return to its original state or an adjusted state based on new requirements"*. From the perspective of safety management systems, resilience is the "*ability of an organisation to anticipate, circumvent threats to its existence & primary goals and rapidly recover".*

From a social-ecological system, Francis & Bekera (2014) described resilience as the ability of the system to maintain its identity in the face of changes and adverse external shocks and disturbances. It is a measure of the persistence of the systems and their capacity to absorb disturbances and reorganise so as to retain the same functions, structure, identity and feedbacks. They had a similar definition for economic systems, where they defined resilience as *the inherent & adaptive responses to hazards that enable individuals and communities to avoid some potential losses.* It is ability of the economic system to withstand market or environmental shocks while retaining their capacity for efficient resource allocations.

For social systems, they defined resilience as the "*ability of groups or communities to cope with external stresses and disturbances as a result of social, political, and environmental change"* Finally from the perspective of organisational systems, Francis & Bekera (2014) defined resilience as the "*ability to recognize & adapt to handle unanticipated perturbations that call into question the model of competence, and demand a shift of process, strategies and coordination"*. To them, resilient organisations balance between stability and flexibility and adapt themselves in the face of uncertainties, without surrendering control to the uncertainties. They recognize threats to their organisations and make adjustments that will guard against the threats.

Grabowski & Roberts (2016) described resilience from an organisational perspective, as an organisation's ability to respond or bounce back from untoward, surprising or disruptive events, a move toward an adaptive approach to ensuring operational continuity during a crisis. It reflects the ability of a system to absorb and recover from shocks, while transforming its structures and means for functioning in the face of long-term stresses, change and uncertainty (Van der Vegt et al., 2015). Hurricane Katrina was probably unavoidable given today's technology, but the impact of the hurricane on the city could have been reduced with resilience. Resilience also indicates the city's ability to return to normalcy after the disaster. Resilience therefore is the ability of a system, a process, an organisation, or an entity, to adjust and adapt itself before, after, or during an expected or unexpected upset, in order to retain its intended functionality.

Woods (2015) considered resilience from four perspectives: rebound, robustness, graceful extensibility, and sustained adaptability. The concept of resilience as rebound considers the ability of individuals, communities, organisations, or groups to recover from traumatic disrupting events better than others to resume normal functionalities that existed before the disruption. It considers existing capacities that are present before the disruptions, and can be deployed or mobilized to mitigate the effects of the disruptions and return the status quo that existed before the disruption. It also considers how the disruptive events challenges the models instantiated in the base capabilities of the system and triggers learning and model revision. Robustness as a concept of resilience considers the extent to which the system confounds to the worst case scenarios possible in the disrupting event. It considers how brittle the system is at its boundaries – its ability to withstand to a wide variety disturbances and perturbations outside its boundaries, sometimes occasioned by unaccounted changes in scope. Graceful extensibility as a concept of resilience considers how the adaptability of a system extends or stretches during a disruption. Finally, sustained adaptability as a concept of resilience refers to the ability to manage "*the adaptive capacities of systems that are layered networks, and are also parts of larger layered networks, so as to achieve adaptability over longer scales"* (Woods, 2015)

The focus of Resilient Engineering is to enhance the ability of organisations to create processes that are robust, yet flexible, to monitor and revise risk models, and to use resources proactively in the face of disruptions or pressures from conflicting objectives (Hollnagel et al, 2008; 2013). It explains the mechanisms of both failures and successes in terms of variability and functional resonance, and particularly encourages studies of normal operations. (Haavik et al 2016). It assesses changes in the adaptive capacity of an organisation as it confronts disruptions, changes, and pressures (Woods; 2006).

Breakdown and normal system malfunctions do not represent failures in resilience engineering, but the focus is more on the adapting to the complexities of processes and their external relationships. In simpler terms, traditional safety has always focused on things that could go wrong as shown in the bottom half of Figure 2.4. Resilient Engineering focuses more holistically on both things that could go wrong, and things that could go right, perhaps with the exception of the top left hand regions of serendipity and good luck that are beyond anybody. Mishap on the bottom right section refers to unwanted outcomes that in practice have been eliminated (Eurocontrol, 2009). They occur despite best efforts to prevent them and could be said to be the opposite of good luck on the top left section. The argument here is that for a 0.05% probability of failure, there is 99.95% probability of a normal outcome, and as such, focus should be evenly distributed. This way, things are not only prevented from going wrong, but normal outcomes are facilitated.

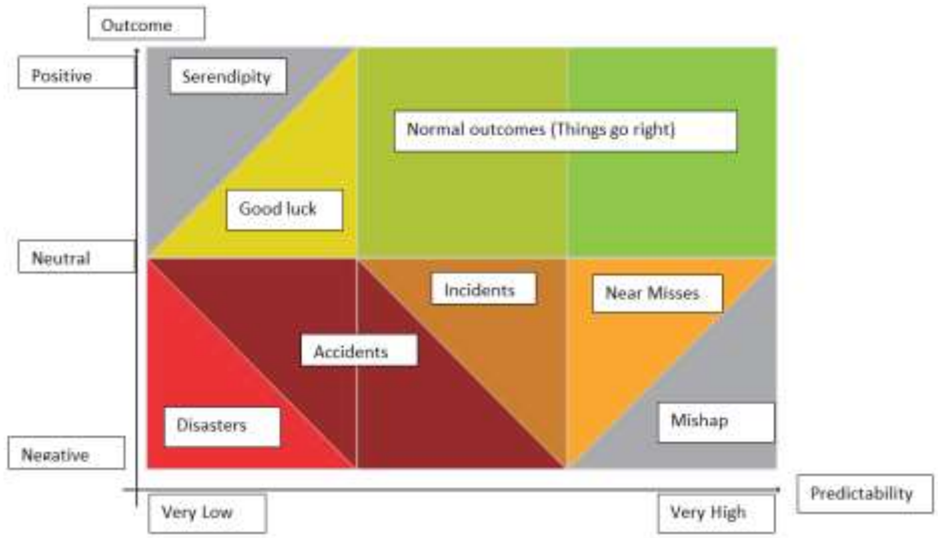


Figure 2.4 – An illustration of Resilient Engineering showing a set of possible outcomes Illustration adapted from Eurocontrol (2009)

Resilient Engineering tries to view accident causation from a systemic perspective, in which accidents result from the complexity of people's activities in an organisational and technical context. With its holistic perspective, these activities in addition to helping to prevent accidents, also helps achieve other goals such as throughput, production, efficiency, and cost control (Dekker et al, 2008). Together with the High Reliability Organisation Theory (Section 2.5.9), Resilience Engineering has emerged as a key concept in safety management due to its perspective that moves away from bureaucracy and a means to manage safety without sacrificing performance (Harvey et al., 2016).

2.5.9 High Reliability Organisations (HRO) Theory

The HRO theory is the focus of the research and as such, more time will be devoted to discussing it than was spent with the seven earlier perspectives discussed. Before proceeding, it would be proper to define the term *"reliability"* with respect to this research. Reliability is the probability that a system, process, a product, a person, an organisation, or an entity will perform as specified, under the specified conditions, and for the specified period of time (Blank, 2004; Stapelberg, 2009). The British Standard (BS EN 13306) defines reliability as *"a measure of the ability of an item to be in a state to perform a required function under given conditions at a given instant of time or during a given time interval, assuming that the required external resources are provided".*

From these reliability definitions, one can therefore say that reliability from an organisational standpoint describes the probability that an organisation will perform the functions it was established to perform, or achieve its organisational goals, within its defined operating envelops and boundaries, and within the time frame set out to achieve those goals.

Research into organisational reliability began in the 1980s at the University of California, Berkeley (Weick 1987; Roberts, 1990). Prior to this, research had been concentrated on organisations that experienced disasters. Perrow (1984), in his Normal Accident Theory, had described the inevitability of accidents in complex organisations with high risk technologies. The HRO researchers argued that some other complex organisations with high risk technologies have consistently prevented and contained catastrophic failures (Roberts, 1990; LaPorte & Consolini, 1998) by creating and reinforcing certain behaviours (Weick & Roberts, 1993). Perrow (1984) had also classified industries into high risk and low risk industries. To him, organisations in the aviation industry, nuclear industry, and military were high risk organisations, while organisations in manufacturing industry, oil and gas industry, and chemical plants were low risk organisations. HRO researchers such as Weick et al (1999), Hopkins (2007), Leveson et al (2009), and Lekka (2011) argued that this classification does not accurately reflect the accident rates experienced in these industries. Despite its 'high risk' classification, the nuclear industry has not experienced more catastrophic failures than the manufacturing industry that are supposed to be 'low risk', neither have the recorded failures in the 'high risk' organisations resulted in greater catastrophe than failures recorded in the 'low risk' organisations.

HRO theory posits that despite inherent complex technologies and tight coupling, organisations could avoid or mitigate the effects of accidents by mindfully adopting and reinforcing certain principles and behavioural patterns. They enhance mindfulness by developing a positive culture that reinforces safety related behaviour and attitudes (Weick & Roberts, 1993). Accidents in complex systems are not inevitable because mindful organisations install processes within their system to prevent and contain catastrophic failures, effectively reduce the probability of serious error, and sustain a consistent safety record over time (Roberts, 1990; LaPorte & Consolini, 1998; Lekka, 2011).

Since the first research in the 1980s, Roberts (1990; 1993), Brown (1993), Schulman (1993), Rochlin (1993), Roux-Dufour (2000), (Weick & Sutcliffe (2001; 2007; 2015), Roberts & Bea (2001), Hollnagel et al (2006), Hopkins (2007), and Sutcliffe (2011) and many others have studied HROs from different theoretical lenses. Despite their diverse views, their point of commonality considers HROs as organisations that are able to sustain themselves despite operating in highly hazardous conditions where failure could have far reaching and potentially catastrophic consequences. HROs are resilient, and able to deal with and react to adverse conditions (Weick & Sutcliffe, 2007; Hollnagel et al, 2006). They are reliability-seeking rather than reliability achieving (Rochlin, 1993; Vogus & Welbourne, 2003), intervening, both to prevent errors and failures as well as to cope with and recover quickly should errors become manifest (Sutcliffe, 2011).

The original research at Berkeley had defined HROs through the lens of an organisation's ability to sustain almost error-free performances over long time periods, as well as the degree to which the organisation could have failed resulting in catastrophic consequences that it did not (Roberts, 1990, Sutcliffe, 2011). These perspectives relied on safety statistics determine an organisation's reliability level. Based on this assumption, an organisation could prevent 99.9% of failures and still be considered as highly reliable. It does not consider that 0.1% chance of failure could lead to catastrophic consequence on the environment, a large population of people, and financial damage that could collapse the organisation. Rochlin (1993) therefore argued in favour of another characterisation of HROs in terms of how effective they are able to manage the 'innately risky technologies through organisational control of both hazard and probability', rather than a reliance on accident statistics.

Another perspective on HROs tried to identify key characteristics that an organisation must have to be considered an HRO. Roberts & Rousseau (1989) identified five characteristics: complexity and tight coupling as described by Perrow (1984); existence of extremely hierarchical structures with clear roles and responsibilities; redundancy of responsibilities and different persons with the authorization to make similar decisions; strong accountability, high performance, and strict use of procedures; and a limited time for major decision making (Lekka, 2011). This school of thought contends that having some of these characteristics does not make an organisation an HRO, but that to be considered an HRO; the organisation must exhibit all the characteristics. Hopkins (2007) notes that adopting this school of thought, drastically limits the possible candidates for high reliability organisations. Recent focus has rather shifted to studying the types of processes and behaviour that could enable organisations to attain reliability.

Weick & Sutcliffe (2001; 2007; 2015) leveraged on the early research at Berkeley to develop five behaviours that enhance the reliability of an organisation. The initial research had studied US Navy's nuclear powered aircraft carriers, nuclear power operations at Pacific Gas and Electric's Diablo Canyon nuclear reactor, and Federal Aviation Administration's an air traffic control. All three were considered to be tightly coupled organisations with complex technologies, and where a minor lapse in judgment could have catastrophic consequences (Weick, 1987; Roberts, 1990; 1993). This early research had identified five characteristics they believed HROs must have (Roberts, 1990; 1993; Roberts & Bea, 2001; Lekka, 2011). These include:

1. Deferring decision making to expertise during emergencies and to hierarchy during normal operations.
2. Management by exception, where managers do not intervene on day to day activities except when absolutely necessary.
3. A climate of continuous training
4. An environment where several communication channels are adopted for safety critical information.
5. In-built redundancy in both human decision making process and in equipment such that safety critical decisions are not left to one person, equipment, or system

Weick & Sutcliffe (2001; 2007; 2015) considered all these and previous research and concluded that the infrastructure of highly reliable organisations was firmly rooted in collective mindfulness. The organisations were seen to make collective efforts to organise themselves and increase the quality of attention across the organisation. This enhanced the people's alertness and awareness to little details, increasing their ability to detect subtle ways in which contexts may vary, while addressing contingencies. The five HRO principles include:

1. Preoccupation with failure
2. Reluctance to simplify
3. Sensitivity to operations
4. Commitment to resilience
5. Deference to expertise

The first three reliability enhancing behaviours: preoccupation with failure, reluctance to simplify, and sensitivity to operations, deal with the capacity of the organisations to anticipate unexpected problems. The last two reliability enhancing behaviours: Commitment to resilience and deference to expertise are concerned with the capacity of the organisations to contain the unanticipated problems when they occur. The next section describes these five reliability enhancing behaviours in more details.

Preoccupation with Failure

This heading at first glance suggests that people in HROs are paralyzed by worries of failure. It however means that the organisation is actively seeking signals within the system that could indicate a potential for failure. A preoccupation with failure is an ongoing caution that drives proactive and pre-emptive analysis of possible vulnerabilities and treats any failure or near-miss as an indicator of potentially larger problems (Sutcliffe, 2011). The organisations continuously seek learning and continuous improvement, and are mindful of the potential for a near miss, unsafe condition, minor failure, unsafe acts, or lack of mindfulness to result in catastrophic failure. They are focused on predicting and eliminating catastrophes, not reacting to them. They focus on points of failure by increasing alertness, fighting inertia, looking for new alternatives, identifying errors, and developing processes to prevent failures (Hales & Chakravorty, 2016).

Weick & Sutcliffe (2015) identified five component of preoccupation with failure. The first, which they referred at as "*anomaly",* refers to the cues that would suggest a system or a process has departed from its common order, form, or rule. Cues tend to be weak, mixed and routine and as such could be easily taken for granted. These cues over time develop into clues: hunches about what the cues portend. The progression of cues into clues provides emerging evidence that the anomaly could be potentially significant. Weick & Sutcliffe (2015) called this component "*cues of evolving failure"* In some cases, this may not be apparent until a failure occurs. HROs are mindful of this and are organised to watch out for the cues and clues, avoid a single interpretation of the cues and clues and apply good judgment before they result in a failure. The third component is "*normalizing"*: a redefinition of acceptable risks when the clues become evident. HROs are reluctant to treat unexpected events as normal events, and are wary of adjusting the accepted operating envelopes to normalize an anomaly. The fourth component is "*institutionalized wariness":* scepticism of quiet periods. Long incident free periods often leave organisations with an air of invincibility and a false impression about their reliability. HROs realize that the quiet periods could become incubation periods for disasters and mindfully continue their processes without any form of complacency. The final component is *“doubt as a mind-set”:* an understanding that existing insights must be doubted as it is impossible to know and understand everything in advance in a dynamically complex environment. It does not presuppose lack of confidence, but a realization that an organised spirit of contradiction is invaluable to analyse diverse view points, and all options. They encourage the use of what if scenarios, argumentation, constructive criticism, and scepticism, as they all enhance the variety required to prevent catastrophic failures.

From all the texts reviewed so far, a summary of some preoccupation with failure behaviours expected from highly reliable organisations include the following:

- They identify, document, and categorize all near misses, incidents, and failures
- They identify the root causes of the near misses, accidents and failures
- They painstakingly resolve the root causes with no blame or punitive culture against people that report the incidents, near misses or failures
- They review lessons learned periodically and feeds the lessons back to update their processes
- They actively reward individuals that report near misses, incidents, and failures
- The superiors actively seek out bad news
- There is clear and open communication between superiors and front line staff, and among the staff
- Their plans consider worst case scenarios
- There is a continuous review of processes and procedures to identify potential areas of improvement

Reluctance to Simplify

As shall be seen in section 2.6, oversimplification is probably one of the major causes of incidents. The management at NASA (section 2.6.5) had known for over 11 years prior to the Challenger crash, that the design of the O-rings in the solid rocket booster had a potentially catastrophic flaw. The disregarded several warnings from their engineers about the potential catastrophic implication of launching the rocket at low temperatures. They waived 6 launch constraints related to O-rings that could have prevented the launch, and by extension, the disaster from happening. They *oversimplified* the problem and wrongly defined it as an *acceptable risk.* Similarly, the management at NASA was aware, prior to the Columbia crash, of previous similar problems with the foam, but since those similar problems did not lead to mission compromising conditions, they accepted it as a norm. They were aware that foam formation was a deviation from the design criteria, but once again, they *oversimplified* and considered this as an acceptable risk. With time, it became a norm – a norm that would lead to another catastrophic. Vaughan (1997) in her review and analysis of the Challenger crash called this oversimplification a *"normalization of deviance",* a situation where *"people within the organisation become so much accustomed to a deviant behaviour that they don't consider it as deviant, despite the fact that they far exceed their own rules for the elementary safety"*

In her analysis of the normalizing of deviance that occurred in the case of the Challenger disaster, Vaughan (1997) noted that during the developmental phase, the group that assessed the joints on the solid rocket boosters to investigate the limits and capabilities of joints performance initially interpreted their findings as deviations. The more tests they conducted, the more reinterpreted the results as within the boundaries acceptable risk, gradually normalizing the deviations. This normalization, or oversimplification, would eventually lead to the crash of the shuttle.

The other disasters discussed each had elements of oversimplification at the root of its causation. The operator at the Chernobyl plant (section 2.6.4) disabled the automatic shutdown systems to perform the test to establish the length of spin of the turbines while supplying power to the main circulating pumps should there be a loss of the mains electricity power supply. They had “successfully” done this in the past, and therefore accepted this norm. Bypassing or disabling safety systems could potentially lead to an incident as the management should have known, but they *oversimplified* and accepted this as a tolerable risk. Before the BP Texas City incident (section 2.6.7), there had been previous events such as leaks, vapour releases, and fires involving the isomerization process unit in the past, but these events were *oversimplified* as acceptable risks. The zone classification for the isomerization unit was oversimplified and considered non-hazardous in earlier designs. *The Titanic* (section 2.6.2) had received 6 warnings from other ships about drifting ice, yet the ship continued to move at near the ship’s maximum speed of 44 kilometres per hour. To them, it was an accepted risk and there was no need to reduce speed. The lookouts also noticed some haze within the horizon ahead of them but failed to report it despite earlier instructions to keep a sharp look out for small ice and growlers. It was also an acceptable risk to them. These were acts of *oversimplification* would lead to the eventual sinking of the titanic.

Highly reliability organisations continuously balance simplification and standardization of processes, with actively seeking to avoid undue generalisations on how and why things work or fail. Highly reliable organisations have standardized processes. They however put a lot of emphasis on probing deeper, and asking more questions to get to root causes of failures or potential failures. They take nothing for granted. They understand that scepticism helps to refine processes, and they encourage people to think outside the box and challenge the norm.

A reluctance to simplify interpretations promotes a thoughtful, data-driven process that considers the uniqueness of a problem before applying a solution (Hales & Chakravorty, 2016). It focuses on HROs’ ability to collect, analyse and prioritise all warning signs that something may be wrong and avoid making any assumptions regarding the causes of failure (Weick & Sutcliffe, 2007; Lekka, 2011). It involves actively seeking divergent viewpoints that question received wisdom, uncover blind spots and detect changing demands (Sutcliffe, 2011), and discourages the form-fitting application or popular ‘best practice’ solutions to problems without thorough consideration of the problem's unique context (Hales & Chakravorty, 2016).

From the literature reviewed, some reluctance to simplify behaviours includes the following:

- They value and reward scepticism and “outside the box thinking”
- People in different strata of the organisation actively walk the process to identify potential flaws.
- They create sessions for people to critique and challenge the process
- They take decisions as soon as potential loopholes in the process are established.

HROs realize the dangers of simplification, which gives the people a false sense of knowledge, potentially causing them to limit their perspectives and the precautions they could normally take, as well as the level of undesired consequences they could imagine. They take nothing for granted (Sutcliffe, 2011). Before the Columbia crash (section 2.6.5) that had multiple fatalities with huge negative financial and reputational impact, NASA oversimplified the Columbia shuttle’s foam that shed 82 seconds into the flight, insisting that it was a maintenance issue which was normal and could be fixed back on the ground (Weick & Sutcliffe, 2015). This had been a recurring issue at NASA for over 22 years and they failed to investigate why the foam continued to be shed despite that the occurrence was outside the design and operating envelopes. Sutcliffe (2011) therefore concludes that prevailing norms in HROs should convey such messages as, ‘take nothing for granted’, ‘don’t get into something without a way out’, ‘we know that we do not know, but we do not even know what we do not know’

Sensitivity to Operations

Highly reliable organisations are constantly responsive to the details of their operations, with the right staffing, competence levels, and motivation. They are able to detect and competently react to slight changes in their process. Sensitivity to operations refers to the mixture of awareness and alertness that organisations have with respect to the expected interactions with complicated and often opaque systems, and the actions that unfold in real time (Weick & Sutcliffe, 2015). It means creating and maintaining an integrated big picture of current situations through ongoing attention to real-time information (Sutcliffe, 2011). It recognizes that a solution to one problem may create another and therefore considers process-wide measurement to be essential (Hales & Chakravorty, 2016). They therefore equip the frontline team members to be mindful of current operational realities and to make small adjustments required to keep the process within the operating limits. In a process plant, small adjustments could be tightening of bolts to stop a vibration. Inability to make this small adjustment could result in equipment failure or loss of containment, which could combine with other forces with the operating environment to lead to further catastrophic failures. The frontline is equipped with trainings and encouraged to promptly identify hazards and communicate variations and understand communications from the process automations, share real time data, and shift issues to experts that better equipped to address the problem.

Some sensitivity to operations behaviours includes the following:

- Meetings are regular with defined terms of reference, and people consider meetings as a part of their duties.
- Individual roles and responsibilities are well defined and everyone understands their roles and performs their roles to the best of their abilities without any coercion
- It is very clear how everyone's roles and responsibilities fits into the big organisational picture
- Frontline staff and leaders are generally free with one another and interact freely in the day to day activities
- People generally get involved in jobs outside their competencies without coercion

- People are rewarded for getting involved in jobs outside their competencies
- People actively seek and receive feedback. They perceive feedback as constructive exercises
- Leaders continuously work with staff to monitor workloads and would collectively determine need for additional resources.

Commitment to Resilience

This is the first of the two HRO principles that deal with the capacity of the organisations to contain or recover from the unanticipated problems after they occur. It is concerned with the ability of organisations to not only effectively anticipate errors but also to cope with and bounce back from errors and 'unexpected events' (Weick et al., 1999; Weick and Sutcliffe, 2007; Lekka, 2011).

Leaders and employees in highly reliable organisations are competent and prepared to respond to failures despite the vagaries of external influences. They are able to quickly recover from the effects of failure, and apply the learnings from the failure. Commitment to resilience relies on soft skill such as improvisation, learning, multitasking, adapting, communication, and network building. Highly reliable organisations with commitment to resilience first of all spend time to improve their ability and capability to anticipate. They create, improve and revise plans and procedures and incorporate the lessons from their experience. They thereafter develop the capacity to contain and recover from the failures should they occur.

HROs commit to resilience through competence development, clear emergency response processes, emergency drills, contingency plans, awareness of key contacts in case of emergencies, and building shared trust among the staff and management. Resilience is the difference between an organisation that faces a disaster and recovers from it and another organisation that faces a similar disaster and goes into extinction. Some behaviour of organisations with commitment to resilience includes:

- Leaders and staff work together to identify learning and development gaps and close them.

- People generally have more than enough skills for their jobs and to act during emergencies.
- Emergency response and contingency plans are robust and implementation is a shared responsibility among all staff.
- Everyone trusts one another and relies on one another during emergencies.

Deference to Expertise

This is the second of the two HRO principles that deal with the capacity of the organisations to contain or recover from the unanticipated problems after they occur. It shows a clear separation of responsibilities during normal operations and during emergencies. HROs rely on a hierarchical structure with clearly defined reporting structure, where roles and responsibilities are clearly defined during normal operations. Everyone knows who the boss is and everyone functions based on the clear cut roles and responsibilities matrix. During emergencies however, decision making is deferred to people with the most subject matter knowledge and experience to resolve the emergency, irrespective of their rank with the organisation (Weick, 1999; Weick & Sutcliffe, 2015; Hales & Chakravorty, 2016). The chief executive of an organisation will receive instructions from a security person, who will assume leadership during a security related emergency irrespective of rank.

Deference does not equate to submission (Weick & Sutcliffe, 2015), but includes a pattern of respectful yielding, with full consideration and awareness of the limits and boundaries of each individual's experience and expertise. Deference includes a pattern of domain-specific knowledge: knowledge gained through first-hand experience in a particular domain, rather than book knowledge. It also includes a compressed and generalizable experience, as well as relative expertise. The organisation or team reverts back to the hierarchical structure once the emergency is over.

Organisations that defer to expertise during emergencies exhibit the following behaviours:

- There is a mutual respect for one another's jobs.
- No job is considered more important than the other.

- People are encouraged to take expert decisions during emergencies.
- Most senior persons yield responsibilities to persons with most expertise during emergencies.
- The experts accept responsibilities professionally, and yield back after the emergency.
- Expertise for all emergencies is generally available.
- People feel responsible until emergencies are resolved.

The following case study summarizes the five HRO principles. Andrews (2012) and Shell (2012) both made references to the incident. The research obtained details of the incident in the course of the interviews, as well as in internal process safety training slides designed for their employees in the aftermath of the incident. A multinational oil company in Nigeria was engaged in remediation and crude oil pipeline leak repair, when the site exploded, leading to seven fatalities, multiple injuries, months of lost production, hundreds of job losses, environmental concerns and organisational reputation damage.

Investigations revealed the following. Oil was reported seeping out along the right of way of a crude and condensate trunk line at a previously clamped site. Access to the site was achieved after 6 days, the delay being mostly due to constraints with the terrain and coordination of stakeholders. The source of the leak was confirmed to be a pipe line clamp installed on the pipeline as a result of previous oil theft activities. Initial repair efforts commenced without the pipeline being shut-in or depressurized. During the repair, the leak got substantially larger, resulting in a loss of containment, and forcing the team to withdraw from site. Shutdown of some upstream facilities was initiated but as the downstream facilities were still producing, backflow to the site continued. Local community issues reportedly prevented access to leak site for two days, increasing the size of the spill. Efforts to recover the spill finally restarted using two water pumps and a swamp buggy. The explosion and the fire occurred during this process of spill oil recovery.

Further investigations revealed that the attempted repair work on the pipeline happened while the pipeline was pressurized. Secondly, a portable spark generating crude evacuation pump was used at the site contrary to the procedure. Thirdly, the work permit was signed by someone in the office, a long distance away from the remote field location. In addition, the site supervisor, and the site HSE supervisor were reluctant to shut down the site when the lapse was spotted, neither were they able to get confirmation from the responsible manager in the office to shut down the site. A site shutdown would have meant the shutdown of all the fields flowing through that trunk line, a potential loss of several thousands of barrels of oil per day. The superiors were reluctant to take such decision despite advice from the frontline. Just before the disaster, the frontline tried to contact their superiors, but it was close to lunchtime and the approval was not obtained. The date is still remembered annually as a dark day in that organisation's history, and a day to reinforce safety.

There was some evidence of failure of *preoccupation with failure*. The potential for disaster could have been identified during a toolbox or kick-off meeting. Such a meeting could have identified the hazards and planned for control and recovery measures. Even if the hazards were identified, was there an adequate management support to ensure the proposed recommendations from hazard and effect management process is effected? There may have been *oversimplification* by everyone involved and some operating envelopes eroded. One may ask: was this the first time of violating such procedure? Were people punished? Should they have been punished? Did the organisation *over simply,* and accept the violations as acceptable risks? Why were the superiors reluctant to take action? Could that be an indication of the organisation's reliability? There are also some questions around *sensitivity to operations:* Should the site supervisors be on site without some level of leeway to make field decisions? Should such decision making responsibility be left in the office? How effective was the communication between the field and the office? Did the responsible person have enough expertise to know the effect of the hazardous condition created? Additionally, the team deferred to hierarchy instead of *deferring to expertise* in the face of an imminent disaster. To have noticed the danger and made a push to shut down the site, there was obviously some level of expertise onsite. They however relied on hierarchy and paid for it with their lives. Finally, the organisation showed a strong *commitment to resilience* by immediately understanding the impact such a disaster could have on its existence and embarked on an elaborate incident review process, sensitization campaign, and implementation of learning from the incident. Till date, the organisation has adopted a day each year to remember their commitment towards avoiding a repeat of the disaster.

It is therefore clear that organisations that want to remain competitive must begin to develop HRO mind-sets irrespective of the complexity of their systems or the coupling of their processes. The HRO theory is not just another theory that seeks to prevent incidents, but an application of the principle of mindfulness to everyday organisational processes and activities. Embedded within this is the mindful application of different safety enhancement, organisational improvement, and incident prevention strategies. This means that all of the seven perspectives discussed from section 2.5.2 to section 2.5.8 are all or could all be embedded within the HRO theory. An organisation adopting the HRO theory would have within its processes one or more of these perspectives; as well as any other initiatives it would consider useful and practical to achieve its objectives. For instance, most nuclear organisations are generally considered as high reliability organisations. They have a combination of these perspectives, including defence in depth, inherently safer design, energy barrier model, resilient engineering, as well as may other initiatives to enhance reliability. For this reason, this research has adopted the high reliability organisation theory as the perspective of choice for this research. The research hopes to examine organisations and identify the behaviours that enhance or limit reliability and hopefully adopt these behaviours to improve diverse organisations. The research shall also discuss some incidents that have occurred in the past and attempt to identify the mindfulness behaviours, if any that led to the incidents. It argues from the background that most incidents are mostly due to the lack of mindfulness of the organisations and the actors involved. This argument forms the background for the next section.

2.6 Research Perspectives on Disasters

2.6.1 Introduction

Within the late twentieth and the twenty first centuries, the incidence of disasters has accelerated, most of which could not be predicted, but became subjects of retrospective predictability after the fact. This increase is due in part to the increasing complexity of the world and its technologies (Taleb, 2010), and the increasing rate of natural hazards as a result of increasing populations and environmental changes (Rougier et al, 2010). Between 1900 and 2017, there have been 8,437 disasters linked to technology with over 100,000 fatalities (Emdat.be, 2017). According to data from Emdat.be (2017), the number of disasters, the total fatalities recorded, the total persons affected, and the total asset damage, have all been on the increase since the 1970s and have continued to increase exponentially. The graph below shows the number of disasters per continent within this period. The period between 1999 and 2006 recorded the most number of disasters with an average of about 340 disasters every year. Apart from Oceania that had relatively few numbers of disasters within the years under review, all other continents recorded large increase in the number of disasters.

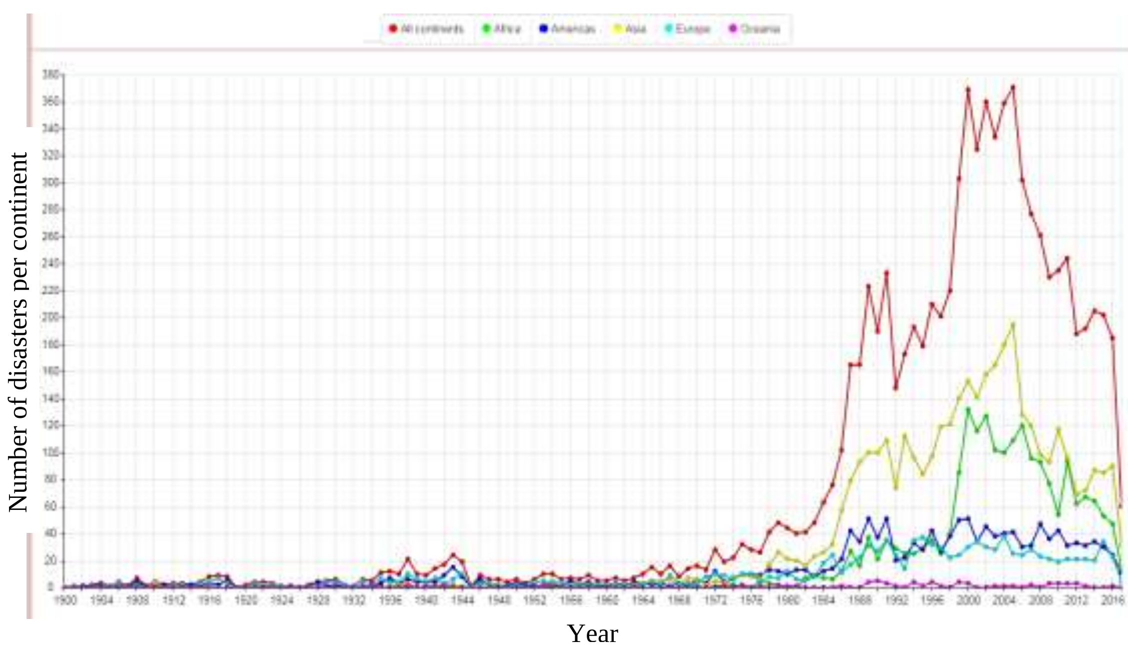


Figure 2.5 – A graph of technology related disasters from 1900 to 2017 showing exponential increase in disasters from the 1980s. Source Emdat.be (2017)

Similarly, figure 2.6 shows the disaster trends in terms of the total fatalities. There was an exponential increase in the number of fatalities from the 1980s, peaking at over 12,000 fatalities in 2002. The lowest number of total fatalities due to technology in a year has been about 6,000 in 2008 – 2013, and in 2016. 11,000 fatalities were recorded in each of 1987, 2000, and 2005.

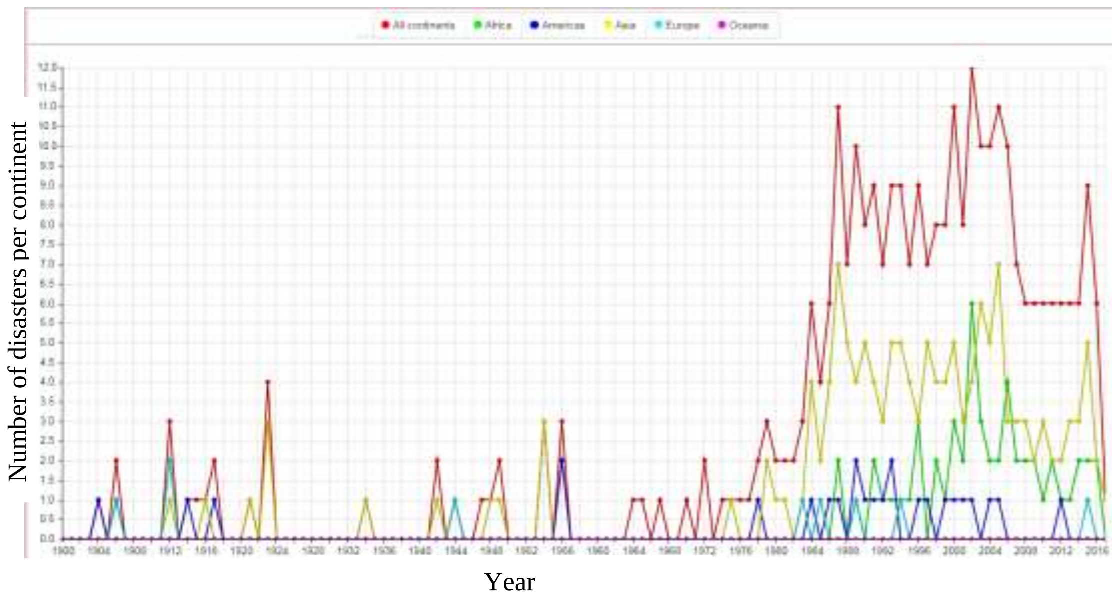


Figure 2.6 – A graph of fatalities from technology related disasters from 1900 to 2017 showing exponential increase in fatalities from the 1980s. Source Emdat.be (2017)

Figure 2.7 shows the total financial value of the asset damage in US dollars, scaled to the 2016 value of the US dollars. As expected, the values increase exponentially from the 1980s. US$1 billion was lost in 1984, US$6 billion in 1986, US$13 billion in 2002, and US$22 billion in 2010.

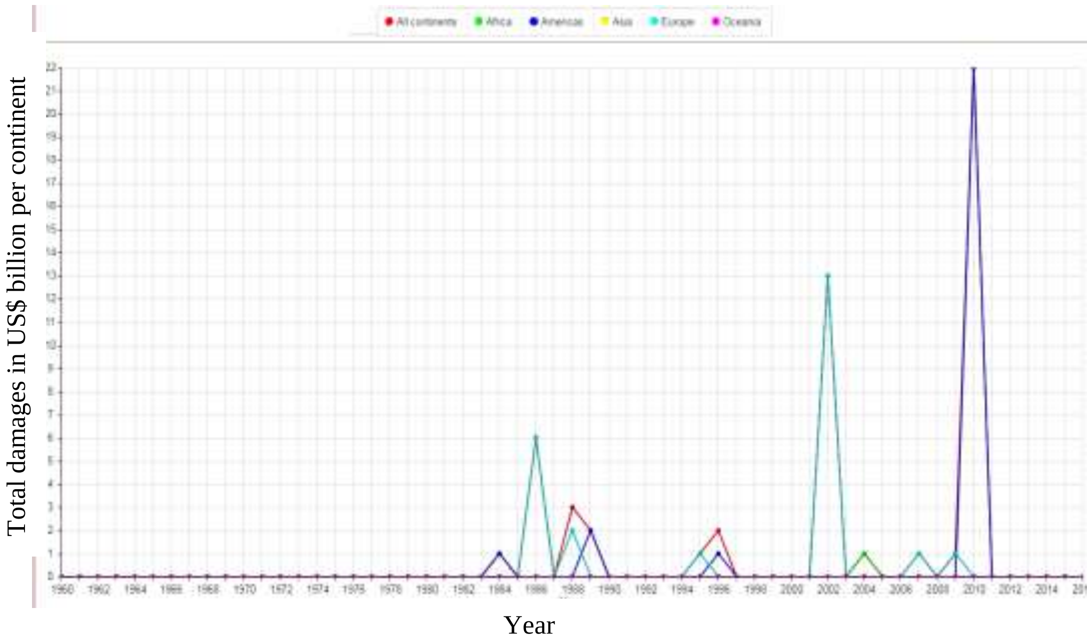


Figure 2.7 – A graph of economic damages from technology related disasters from 1900 to 2017 showing exponential increase from the 1980s. Source Emdat.be (2017)

Considering the same period, natural disasters have also followed the same trend as technology related disasters. Figures 2.8, 2.9, and 2.10 show the number of natural disasters, the total persons affected (not fatalities), and the total damage in US dollars recorded from the disasters between 1900 and 2017. Between 1900 and 1950, the largest number of natural disasters recorded worldwide was 13. The occurrence of natural disasters increased exponentially also from the 1960 and have remained so till date. In the year 2000 alone, about 530 cases of natural disasters were recorded worldwide. Since 1997, the lowest number of natural disasters recorded has been 330. Similarly, before 1965, apart from a few odd years where about 25 million people were impacted by natural disasters, the impacts were minimal relative to the scale and magnitude recorded after 1965. In 1965, over 130 million people were impacted by different forms of natural disasters. The trend has continued to increase till date with a peak at about at about 630 million people in 2002. Finally in terms of asset damage scaled to 2016 US dollar value, the total economic damage also increased exponentially to a peak of about US$390 billion in 2011. Before 1976, the maximum economic damage was US$20 billion.

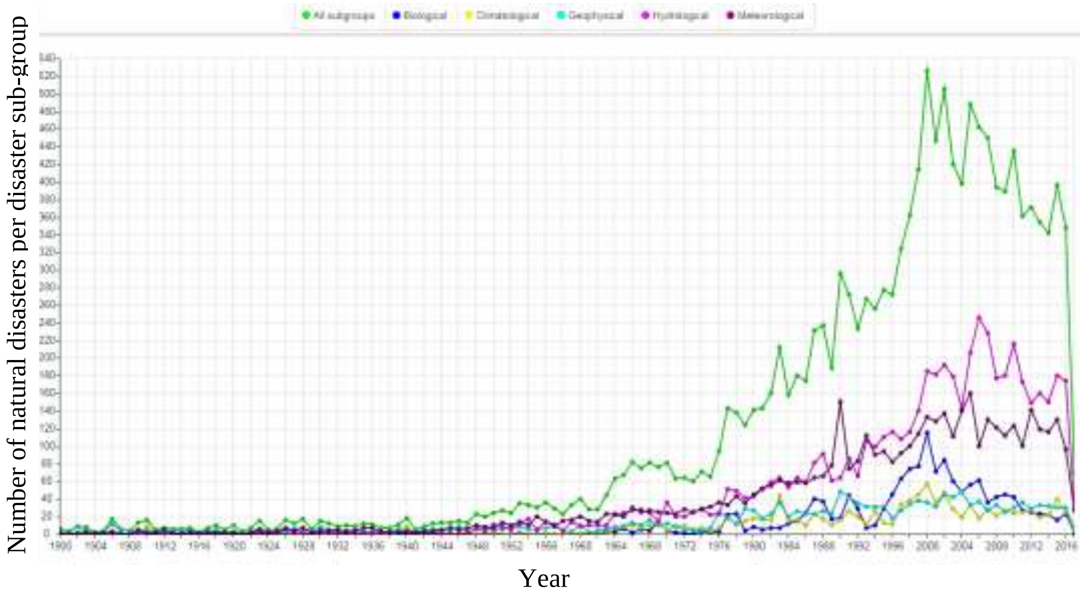


Figure 2.8– A graph of number of natural disasters from 1900 to 2017 showing exponential increase from the 1960s. Source Emdat.be (2017)

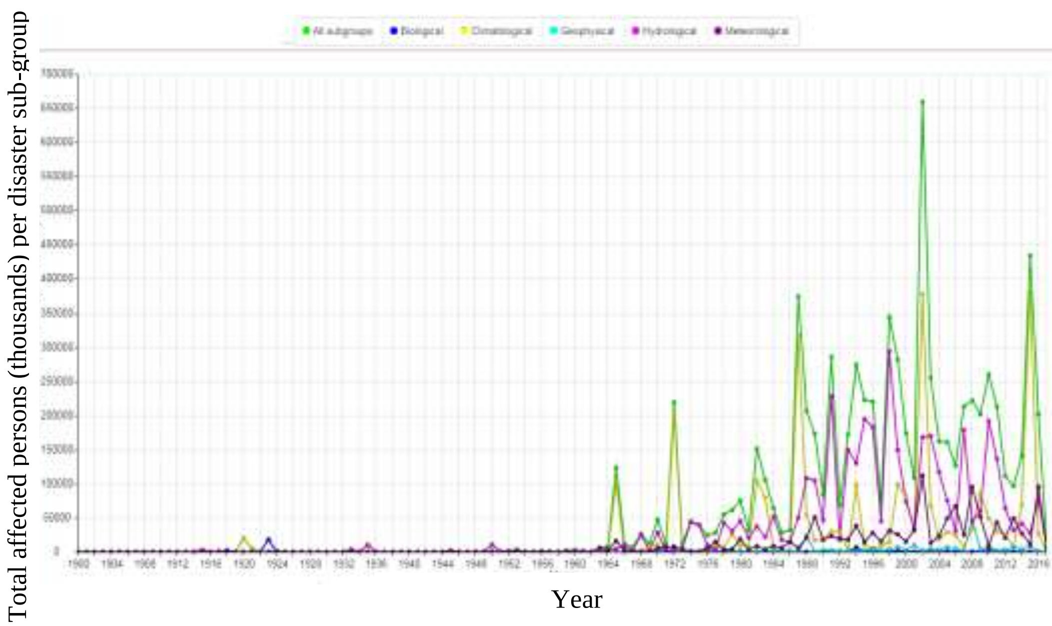


Figure 2.9 – A graph of number of persons affected by natural disasters from 1900 to 2017 showing exponential increase from the 1970s. Source Emdat.be (2017)

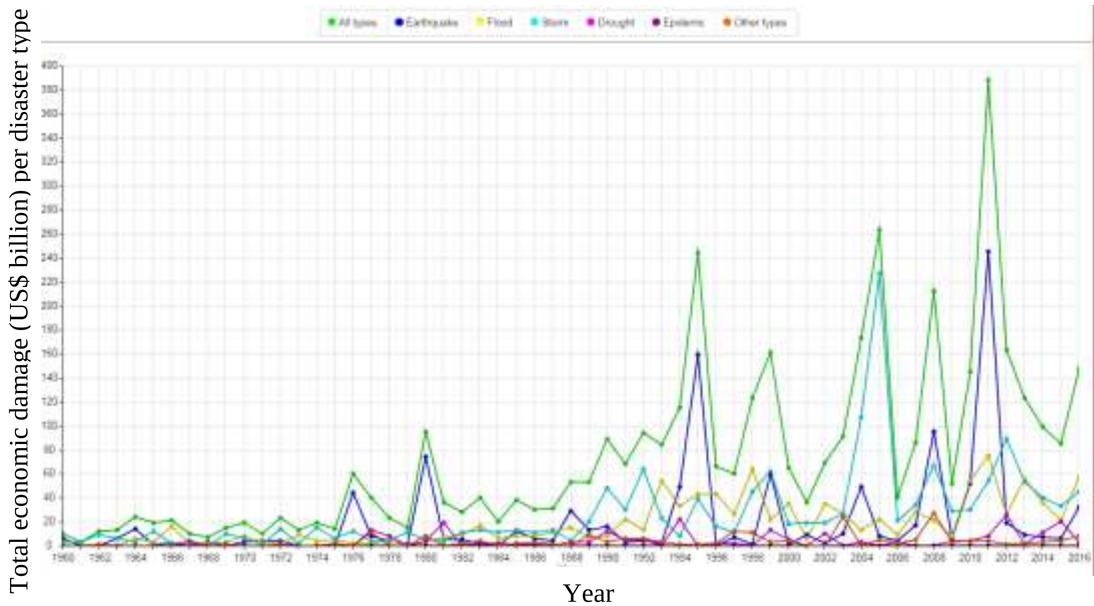


Figure 2.10 – A graph of economic damages from natural disasters from 1900 to 2017 showing exponential increase from the 1970s. Source Emdat.be (2017)

Table 2.3 shows a timeline of some major industrial disasters between 1906 and 2013. It is not a comprehensive list, but has been gleaned from the Sandbox (2017) statistics to show the scale and increasing frequency of industrial disasters over the years. Table 2.4, also gleaned from Sandbox (2017), show a timeline of some major oil spills between 1967 and 2010. It is also not a comprehensive list, but has been extracted to highlight the increasing frequency and severity as the years have progressed. There were a number of spills recorded between 1992 and 2010, but these were excluded here to highlight the 2010 deep water horizon that recorded heavy fatalities, very huge volume of oil spilled, huge financial impact, and posed a massive public relations nightmare for the organisation.

Table 2.3 – A table showing some major industrial disasters timeline arranged chronologically between 1906 and 2013. Source Sandbox (2017)

SOME MAJOR INDUSTRIAL DISASTERS TIMELINE				
Year	**Day**	**Incident**	**Location**	**Impact**
1906	10-Mar	Coal dust explosion	Courrieres, France	1099 fatalities
1942	26-Apr	A coal dust and gas explosion in a mine	Benxi Liaoning, China	1549 fatalities
1947	16-Apr	Fire near 2,300 tons of ammonium nitrate on S.S. Grandcamp causes explosion	Texas City, Texas, USA	581 fatalities
1976	10-Jul	ICMESA, a chemical manufacturing plant, releases dioxins	Seveso, Italy	3,300 farm animals killed
1976	10-Jul	(TCDD)	Seveso, Italy	80,000 animals are later slaughtered
1984	2-Dec	42 tons of lethal methyl isocyanate	Bhopal, Madhya	2,259 (immediate fatalities)
1984	2-Dec	leak from the Union Carbide pesticide plant		An estimated 2,500 are believed to have died since from the exposure
1984	19-Nov	Explosions at a Liquid Petroleum Gas tank farm	San Juanico, Mexico	500 fatalities
1986	26-Apr		Prypiat, Ukraine	50 fatalities due to radiation
1986	26-Apr	Explosion during an unauthorized test at the Chernobyl nuclear power plant		3,940 fatalities due to radiation induced cancer and leukemia
1989	24-Mar	Exxon Valdez, an oil tanker, spills 260,000 to 750,000 barrels of crude oil into the sea	Prince William Sounds, Alaska, USA	100,000 to 250,000 seabirds
2000	13-May	Explosion at a fireworks storage depot	Enschede, Netherlands	23 fatalities
2013	24-Apr	Rana Plaza, a building containing several factories, collapses	Savar, Bangladesh	more than 1,100 fatalities

Table 2.4 – A table showing some major oil spill timeline arranged chronologically between 1967 and 2010. Source Sandbox (2017)

SOME MAJOR OIL SPILLS BETWEEN 1967 AND 2010				
Year	**Day**	**Incident**	**Location**	**Impact**
1967	18-Mar	Torrey Canyon ran aground	Scilly Islands	38 million gallons of crude oil
1977		Blowout of well in Ekofisk oil field	North Sea	81 million gallons of oil
1978	16-Mar	Amoco Cadiz wreck	Portsfall, France	68 million gallons of oil
1979	3-Jun	Exploratory oil well Ixtoc 1 blew out	Gulf of Mexico	140 million gallons of crude oil
1980	30-Mar	Floating hotel in North Sea collapsed	Stavanger, Norway	123 Fatalities
1983	4-Feb	Nowruz Field platform spill	Persian Gulf, Iran	80 million gallons of oil.
1983	6-Aug	Spanish tanker Castillo de Bellver caught fire	South Africa	78 million gallons of oil
1988	6-Jul	Piper Alpha explosion	North sea	166 fatalities
1988	10-Nov	Odyssey spilled	Newfoundland, Canada	43 million gallons of oil.
1989	24-Mar	Exxon Valdez, an oil tanker, spills crude oil into the sea	Alaska, USA	11 million to 32 million gallons of oil
1991	23-Jan	Deliberate release	Kuwait	460 million gallons of crude oil
1991	11-Apr	Haven spill	Genoa, Italy	42 million gallons of oil
1991	28-May	ABT Summer explosion	Angola	78 million gallons of oil
1992	2-Mar	Well spill	Uzbekistan	88 million gallons of oil
2010	24-Apr	Deep Water Horizon	Gulf of Mexico	11 fatalities, 210 million gallons of oil

With increasing stakeholder demands, organisations are increasingly improving their technologies and processes to enhance productivity and competitiveness. This has had the unintentional consequence of increasing the hazards associated with these processes, and as such, organisations must evolve their processes to mitigate these hazards. A trend of major safety incidents over the years ties the causative factors to mostly organisational and individual errors. Moura et al (2015) considered organisational contributions to be the major cause of industrial incidents. To them, recent major safety incidents in complex industrial systems were deeply connected to human and organisational factors, leading to catastrophic consequences. This research has studied some major disasters within the last century to understand the relationship between the disasters and organisational causative factors. It tried to question if these disasters could have been prevented through organisational mindfulness. This research believes that by understanding the contributions of lack of organisational mindfulness, if any, on these disasters, it could potentially develop a framework to help eliminate disasters and their effects. This research will present seven of the disasters studied. These seven disasters have been selected as they all have lack of organisational mindfulness at the core of their causative factors. These seven disasters were selected due to the abundance of literature on them. To select cases with little literature available, this research might have to rely on direct contact with the stakeholders. Since these incidents happened between 1912 and 2010, collecting primary data might be inappropriate as memories may have faded and key persons might not be readily available. The research will continuously make references to these disasters as the thesis develops. These seven disasters occurred in four different industries, in different countries and across different continents and are arranged in order of occurrence. These are:

1. The Titanic disaster (1912)
2. The Bhopal disaster (1984)
3. The Chernobyl nuclear disaster (1986)
4. NASA's Challenger (1986) and Columbia (2003) disasters
5. Piper Alpha disaster (1988)
6. BP Texas City disaster (2005)
7. BP Deep water Horizon disaster (2010)

These disasters are described below in a chronological order.

2.6.2 Titanic Disaster (1912)

Titanic sank in 1912, killing 1514 passengers and crew (Howells, 1999). Labib & Read (2013) attributed the Titanic disaster primarily to poor decision making, insufficient provision of critical equipment, organisational procedural factors, over confidence, and other human factors. Although there were obvious environmental factors and technological factors, perhaps the human factors exacerbated the effects these would have otherwise had on the incident. The Titanic was built as the world's biggest and most luxurious ship at its time (Labib & Read, 2013). It was built by The White Star Line to fend off competition from its rivals, Cunard, Hamburg America, and Norddeutscher Lloyd. It was built and equipped with the latest technology in its time and could accommodate 2228 passengers and crew (Labib & Read, 2013). When Titanic hit an iceberg during its maiden voyage in 1912 at a high speed, its superstructure catastrophically failed, ripping the hull and damaging 5 of its 16 watertight compartment. About 1514 passengers and crew lost their lives (Howells, 1999). The visibility was poor, and a mild winter had caused large numbers of icebergs to shift off the west coast of Greenland (Ryan, 1985). These were environmental factors that could potentially lead to a disaster, but could some acts of mindfulness have prevented the disaster?

Ballard (1987) and Ryan (1985) noted that the visibility was very poor and *The Titanic* had received 6 warnings from other ships about drifting ice, yet the ship continued to move at near the ship's maximum speed of 44 kilometres per hour. The organisation prioritized arriving on schedule over safety, thus it was an organisational practice to move at close to the maximum speed despite hazard warnings. A mindful organisation and captain could perhaps have reduced speed due to the dangerous combination of visibility and ice warnings. In addition to this, the lookouts noticed some haze within the horizon ahead of them but did not report it despite earlier instructions to keep a sharp look out for small ice and growlers (Barratt, 2010). When the iceberg was finally reported by the spotters, the bureaucratic and hierarchical chain of command made it difficult to take immediate action to steer the ship away from the iceberg. The ship eventually avoided a head-on collision, but glanced the iceberg with its starboard side, making the sinking inevitable.

Reports have shown that the fatality could have been minimized had the passengers and the crew been trained or prepared for an emergency of such magnitude (Hutchings & de Kerbrech, 2011). First, the distress calls inaccurately directed potential rescuers 13.5 nautical miles away from the ship’s position (Ballard, 1987). Secondly, most passengers and crew did not understand the implication of the impending disaster and ignored the warnings to put on their lifebelts and muster (Bartlett, 2011). In addition, the available lifeboats were barely enough to accommodate about half of the total passengers on board (Hutchings & de Kerbrech, 2011), a clear organisational lapse in judgment. Furthermore, there was clear leadership ineffectiveness (Cox, 1999), as the captain, an experienced seaman with zero experience in emergencies, was paralysed with indecision. He failed to organise his crew, gave ambiguous and mostly impractical instructions, did not follow up on his instructions, did not communicate effectively with his crew, and failed to give the order to abandon ship. On the other hand, the crew, with minimal lifeboat training, was ill prepared for the emergency. Emergency drills were inadequate, the lifeboats were only partially provisioned, and most of the crew had no clue about the order of boarding, or the capacity of the lifeboats. Cox (1999) reckons that over 500 people could have been saved had the crew utilized the right capacity on the lifeboats.

The Times Dispatch

Titanic, Giant White Star Liner, Sinks After Collision With Iceberg on Her Maiden Voyage, and 1,800 Lives Are Reported Lost in World's Greatest Marine Disaster

WIRELESS CALLS SEND V'SSELS RUSHING TO AID OF SEA COLOSSUS

OF ALL ON BOARD ONLY 675 KNOWN TO HAVE ESCAPED DEATH IN OCEAN

Figure 2.11 – A Newspaper clipping from 1912 showing the consequence of the Titanic disaster (Labib, 2014)

With the foregoing, it is clear there were environmental causative factors that contributed to the disaster, however, human and organisational mindfulness could have nullified the threat of the environmental factors, or at least reduced the severity and impact of the incident. This therefore advances this research's argument that human and organisational errors are the major causative factors in disasters. Under the weight of public relation campaigns and litigations resulting from the disaster, White Star Line became defunct in 1934.

Table 2.5 maps all the causative factors of the Titanic disaster already identified in the text above in terms of the five high reliability organisation principles. Each column represents an HRO principle and all the causative factors related with the principle.

Table 2.5: A table that maps the causative factors of Titanic disaster in terms the 5 HRO Principles

Mapping the causative factors of the Titanic disaster in terms the 5 HRO Principles				
Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise
Consideration of arriving on schedule over safety. Failure to report haze within the horizon. Organisational practice to move at maximum speed	Oversimplifying the effects of maximum speed Ignored saveral warnings	Maximum speed despite weather and visibility Poor crew training and passenger instructions Poor comprehension of impending disaster Ineffective leadership Ineffective communication Leadership indecision	Inadequate emergency management procedures Inadequate emergency management training Inadequate lifeboats Inadequte emergency drills Partially provisioned lifeboats No defined orderfor lifeboat boarding	Excessive bureaucracy impeded actions to stear away from the iceberg/reduce speed

2.6.3 Bhopal Disaster (1984)

The Bhopal incident of December 1984 is another avoidable incident that highlights the effects of human and organisational actions and inactions on disasters. On the night of 2nd December, 1984 around 11 pm, an operator at the then Union Carbide's pesticide plant in Bhopal, Madhya Pradesh, India, noticed a small leak of methyl isocyanate gas (MIC), as well as an increasing pressure inside a storage tank. MIC was originally used in World War 1 and it attacks the 'wet' parts of the human body such as the mouth, eyes, nose, and throat. As soon as it enters the lungs, it reacts with bodily fluids and drowns the person from inside (Ishizaka & Labib, 2014). About two hours after the leak was observed, a safety valve failed, and released about 40 tonnes of methyl isocyanate gas (MIC), mixed with other chemicals into the atmosphere. The gas enveloped the neighbouring communities, immediately killing over 3000 residents with the figure eventually rising to about 20,000 (Ishizaka & Labib, 2014). Over 300,000 people were believed to be suffering from serious ill health from its effects 4 years after the incident (Rosencranz, 1988)

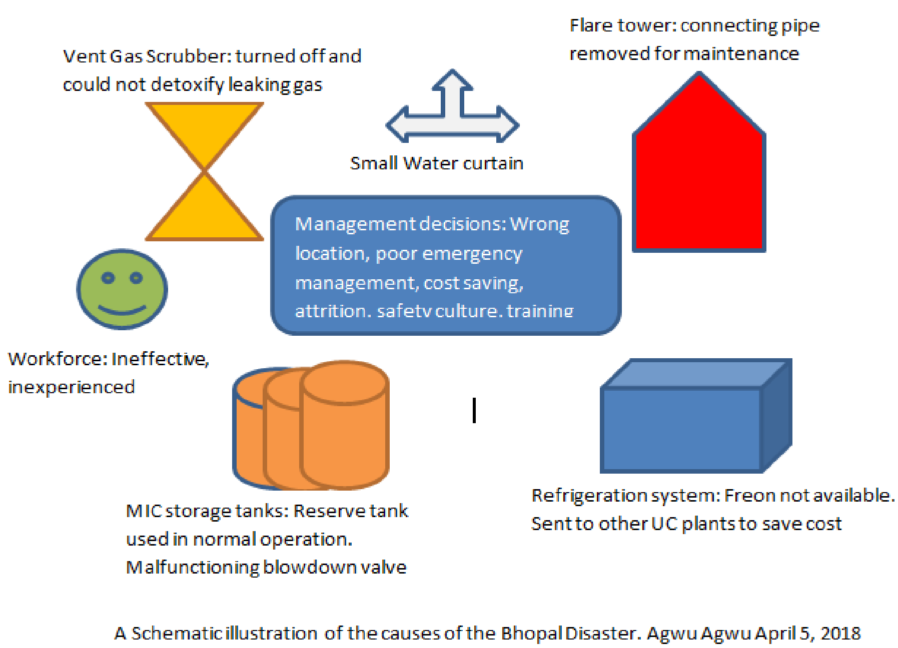


Figure 2.12 – A Schematic illustration showing the causes of the Bhopal Disaster as described in this research

Several investigations concluded that the root causes majorly resulted from series of organisational and individual errors (Rosencranz, 1988; Broughton, 2004; Labib, 2014; Ishizaka & Labib, 2014). Labib (2014) used a fault tree analysis method to identify 10 major reasons that led to the catastrophic release of methyl isocyanate gas (MIC). The first key reason he identified was ineffective workforce. By the 1980s, a combination of widespread crop failures and famine on the sun-continent had led to a decreased demand for pesticides. Increased competitiveness from global pesticide manufacturers further eroded Union Carbide's market share, leading to further decreased profitability and forcing the organisation to consider plant closure and divestment. With these developments, attrition rate for experienced employees increased with no corresponding replacement with equally experienced persons. New and inexperienced personnel were quickly progressed to backfill the attritions, and the entry standards were lowered to attract people to backfill some critical roles. By 1984, the workforce had been reduced by half with no clear investments in technology to justify the reduction. The employees and the management therefore were neither adequately resourced, nor did they have adequate training and experience to manage such a hazardous process.

Labib (2014) identified two other reasons that culminated in the disaster. These were diminished design specifications and ineffective flare tower. Ishizaka & Labib (2014) summarized these as a direct effect of cost cutting initiatives by the organisation. The plant was initially approved for only the formulation of pesticides in relatively small quantities, and as such was located in a light industrial and commercial zone. Pressure from competition led to an increased capacity with no corresponding hazard assessment that would have relocated the plant to a zone that could handle hazardous substances. Other instances of diminished design specifications include replacement of stainless steel piping with a cheaper, but more corrosive carbon steel; manually controlled safety devices instead of the automatically controlled safety devices with back up as used in their West Virginia plant; unavailability of computerized warning systems on the storage tank that could have alerted the personnel of an increasing temperature; lack of a unit storage system; and an ineffective water spray system. At similar Union Carbide plants, there were computerized early warning systems that sensed leaks, monitored rates and concentrations, and were configured to instantly dial out alerts. This was non-existent at Union Carbide, instead, their US$6 million celebrated cost cutting saw a reduction in the number and quality of safety devices. Furthermore, their flare tower was ineffective: there was no redundancy built into it, and the existing flare tower was incapable of dealing with the quantity of the gases released. Finally, the Methyl Iso Cyanate was stored in large batches, a departure from the safe storage process adopted in other Western plants.

Another key reason identified in Labib's fault tree analysis was the resultant effect of poor management decisions. Due to cost cutting initiatives and lack of experience, large sections of the plant were allowed to run outside their design parameters and processes were revised to ensure continued production whist essential components of the system were defective (Ishizaka & Labib, 2014). They decided to shut down the refrigeration unit that would normally cool the methyl isocyanate storage tanks and redirected the freon gas to be used somewhere else. They also made the decision to utilize the reserve methyl isocyanate storage tank in normal operation, instead of leaving it empty for emergencies as it was designed for. As soon as they realized the tank was in use, the process specifies that production must be halted until it is emptied. The management failed to take this decision. Two other critical reasons for the disaster were poor maintenance practices and poor maintenance procedures on the plant. A blow down valve on the methyl isocyanate storage tank was known to be malfunctioning, but was left in service. The main line from a relief valve header to a pressure vent header was known to be faulty, and a jumper line, instead of the correct replacement, was used for the connection, thereby enabling water from a routine washing operation to pass into the methyl isocyanate storage tank. The gauges were also known to be faulty, and as such, the workers ignored early signs of potential failure. In addition, the slip blind process was omitted from existing maintenance procedures, and the procedure omitted the checking of all related lines.

The last three reasons are related to safety: poor health and safety awareness; impaired capability of safety devices; and deficient emergency response procedure. There were no robust emergency response procedures both at the organisational level, and at the civil authorities' level. The danger alarm was sounded after the incident to warn the adjacent residential communities, but was turned off after 5 minutes. It is unclear if 5 minutes is enough time to warn the residents to evacuate. According to Labib (2015), the management did not notify external agencies about the incident, and initially denied the incident when contacted by the authorities. When the authorities finally understood the gravity of the incident, there were undecided for long periods on the proper actions to take. These misinformation and indecisions ultimately increased the severity of the disaster.

In conclusion, the Bhopal disaster could have been avoided through mindful actions of the organisation. According to Labib (2014), a lot of safety events had happened in the years, months, and weeks leading to the disaster, yet the organisation neglected these cues and continued with operations as usual. They ignored warnings from experts who studied the process and predicted a similar incident. It is therefore clear that of gross violations of basic safety practices and a very poor safety culture within the organisation led to this incident. Over 3000 people died immediately as a result (Labib, 2014); over 20,000 people are believed to have died over a 20 year period after the incident as a result (Broughton, 2004); and over 300,000 people were believed to be suffering from its effect 4 years after the incident (Rosencranz, 1988).

Table 2.6 maps all the causative factors of the Bhopal disaster already identified above in terms of the five high reliability organisation principles. Each column represents an HRO principle and all the causative factors related with the principle.

Table 2.6: A table that maps the causative factors of Bhopal disaster in terms the 5 HRO Principles

Mapping the causative factors of the Bhopal disaster in terms the 5 HRO Principles				
Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise
Diminished design specs. Poor design of flare tower. Choice of cost over quality. Replaced stainless steel with cheaper less durable carbon steel. Wrong plant location. Increased capacity with no corresponding hazard assessment. Manual safety devices instead of automatic. Reduced quality standards. No unit storage system. Ineffective water system. No computerized early waring systems/Impaired capability of safety devices. Poor incident reporting. Poor maintenance procedures.	Revised processes to enable operation outside design parameters. Ignored warning cues. Similar incidents in the past not learned from. Ignored warnings from experts.	Ineffective workforce. Inexperienced workforce. Operating outside design parameters/envelopes. Used emergency MIC tank in normal operations. Shut down refrigeration unit and redirected freon gas. Ineffective maintenance practices. Poor health and safety awareness.	Deficient emergency response procedures. Poor coordination with civil authorities. Alarm turned off after 5 minutes. Late reporting to authorities. Poor coordination with neighbouring communities.	

2.6.4 Chernobyl Nuclear Disaster (1986)

On the 26th of April 1986, during a scheduled exercise to test a potential safety emergency core cooling feature, a nuclear reactor in Chernobyl, Ukraine, suffered a catastrophic power increase that resulted in an explosion in its core. This explosion released large amounts of radioactive isotopes into the atmosphere, causing an open air fire (Medvedev, 1990). Over 40 fatalities were recorded from the April 1986 Chernobyl nuclear disaster in Ukraine. 237 cases of acute radiation sickness were reported, and cancer related deaths from the incident was projected to reach 4,000 (WHO, 2006). Belarus estimates $235 Billion economic damage over 30 years (MFA, 2009), and a similar estimate was expected from Ukraine. Today, the disaster zone remains a ghost town

According to INSAG (1992) and World-Nuclear.org (2016), the Chernobyl power complex was situated about 130 km north of Kiev, Ukraine, and about 20 km south of the border with Belarus. It consisted of 4 Soviet designed, graphite moderated, pressure tube type, RBMK 1000 nuclear reactors with 2 more reactors under construction the time of the incident. It used slightly enriched (2% U-235) uranium dioxide fuel, and had 2 loops feeding steam directly to the turbines without an intervening heat exchanger. The process flow is shown in figure 2.7 below.

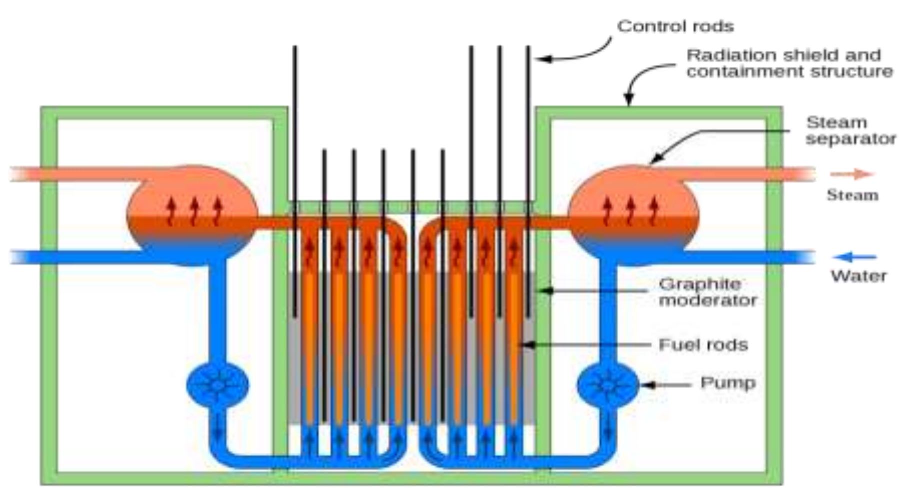


Figure 2.13 – "Diagram of RBMK nuclear reactor schematic, showing the process flow" by Fireice licensed under CC BY-SA 3.0

Before a planned shutdown on the 25th of April 1986, the personnel started to prepare for a test to establish the length of spin of the turbines while supplying power to the main circulating pumps should there be a loss of the mains electricity power supply. This was not a new test. The test was also to determine the effectiveness of the newly installed voltage regulator designs following the previous year's tests where the power from the turbine ran down more rapidly than was expected. The operator disabled the automatic shutdown systems to perform this test, and by the time the operator moved to shut down the reactor, it had already attained a catastrophically unstable condition. There was fuel fragmentation and a drastically increased reactor pressure as result of the interaction between the very hot fuel and the cooling water. This damaged the 4 fuel assemblies, partially detached the cover plate of the reactor, ruptured the fuel channels and jammed all the control rods. There was a steam explosion and fission products were released into the atmosphere. Within seconds, a second explosion occurred, expelling fragments from the fuel channels and about 300 tonnes of hot graphite. The graphite and the fuel became incandescent, generating a number of fires causing the catastrophic release of radioactivity into the environment (World-Nuclear.org, 2016).

The International Nuclear Safety Group (INSAG) in its 1992 report of the immediate and remote causes of the Chernobyl disaster (INSAG, 1992) attributed the causative factors of the disaster to operator error, disabling of safety systems, poor quality of operating procedures, violations of available operating procedures and instructions, design and construction error, negligence, inadequate competency, and inadequate communication were mostly considered to be responsible for the incident. All these are human and organisational causative factors that could have been eliminated with mindfulness behaviour by the organisations and the individuals.

Table 2.7 maps all the causative factors of the Chernobyl disaster in terms of the five high reliability organisation principles. Again, each column represents an HRO principle and all the causative factors related with the principle.

Table 2.7: A table that maps the causative factors of Chernobyl disaster in terms the 5 HRO Principles

Mapping the causative factors of the Chernobyl disaster in terms the 5 HRO Principles				
Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise
Design error. Construction error. Inadequate procedures		Disabling of automatic shutdown systems. Inadequate training. Violating existing procedures. Negligence. Inadequate competencies. Ineffective communication		

2.6.5 NASA Challenger (1986) and Columbia Shuttle (2003) Disasters

On the 28th of January, 1986, NASA's space shuttle *Challenger* broke apart, barely 73 seconds into its flight; while the space shuttle, the Columbia, disintegrated on the 1st of February, 2003 upon re-entering the earth's atmosphere (Labib & Read, 2013). In both cases, all 7 crew members were killed, and hundreds of millions of dollars lost.

Figure 2.14 – "Space Shuttle Challenger explodes shortly after take-off" by NASA for CC public domain

In the Challenger incident, an O-ring seal in its right solid rocket booster failed at lift off. This caused a breach in the joint it was meant to seal, resulting in a chain of events that culminated in the disaster. The report of the presidential commission on space shuttle (PC & Rogers, 1986) found considered poor organisational culture and weak decision making processes to be the key causative factors of the incident, with NASA found to have violated a number of its safety rules. The management had known for over 11 years that the design of the O-rings in the solid rocket booster had a potentially catastrophic flaw. The disregarded several warnings from their engineers about the potential catastrophic implication of launching the rocket at low temperatures and failed to cascade the reports and concerns to senior management. They *oversimplified* the problem and wrongly defined it as an *acceptable risk.* They waived 6 launch constraints related to O-rings that could have prevented the launch from happening. Furthermore, the report considered failures in communication as a major causative factor. The launch was "*based on incomplete and sometimes misleading information, a conflict between* *engineering data and management judgments, and a NASA management structure that permitted internal flight safety problems to bypass key shuttle managers".*

Figure 2.15 – "Challenger crew in the white room before the launch" by NASA for CC public domain

Table 2.8 maps all the causative factors of the NASA Challenger disaster in terms of the five high reliability organisation principles. Again, each column represents an HRO principle and all the causative factors related with the principle.

Table 2.8: A table that maps the causative factors of NASA Challenger disaster in terms the 5 HRO Principles

Mapping the causative factors of the NASA Challenger disaster in terms the 5 HRO Principles				
Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise
	Disregarded warnings about O-ring flaws. Oversimplified flaws Accepted risks on flaws Waived 6 launch constraints. Ignored expert warning not to launch at low temperature	Weak decision making Safety rules violations Communication failure		

The Columbia disaster followed a similar pattern as the Challenger in terms of *oversimplification".* A piece of foam insulation shed off from the external tank of the shuttle during launch and struck the left wing orbiter.

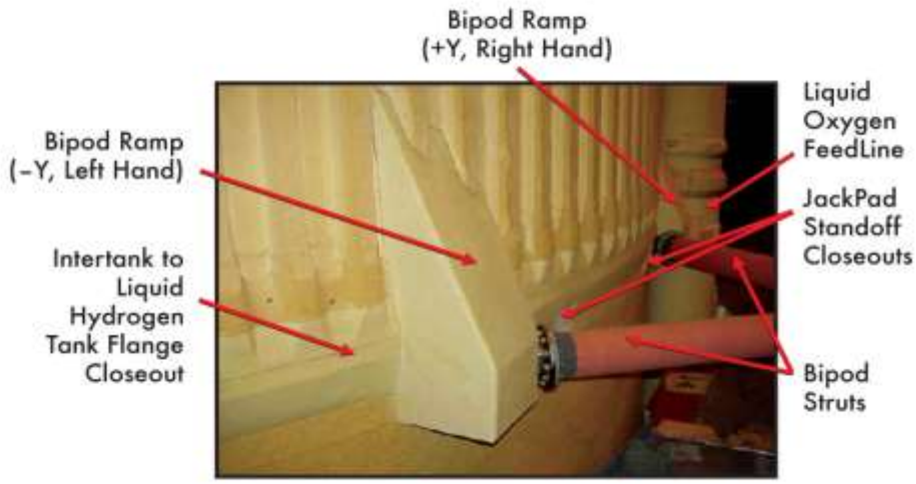


Figure 2.16 – "Close-up photo of the left bipod foam ramp that caused the destruction of the Space Shuttle Columbia" by NASA for CC public domain

The CAIB (2003) attributed the major causative factors to organisational culture, weak decision making, and inadequate risk management process. According to the report, similar problems with the foam had occurred in the past, but did not lead to mission compromising conditions. The organisation therefore once again *oversimplified* and considered this as an acceptable risk. They accepted the deviations from design criteria and with time, these became the norm. The report also concluded that the design of the organisation structure created an error enforcing condition whereby one person was responsible for multiple and often conflicting responsibilities, such as schedule, cost and safety compliance. These are three conflicting responsibilities that should be separated in a mindful organisation, but NASA often had them combined. Finally, the organisation did not demonstrate a preoccupation with failure or a commitment to safety. The crew did not have enough time to prepare for the launch; neither did they have adequate basic personal protective equipment such as safety gloves, helmets, and harnesses. Finally, there were no contingencies built in in case such incident. The report concluded that both a rescue mission and an on-orbit repair by the shuttle astronauts were possible and could have helped prevent the disaster, had NASA built in such emergency response processes into their system. In both cases therefore, organisational and individual errors played key roles in the initiation and escalation of the disasters.

Figure 2.17 – Official portrait of the Columbia crew by NASA for CC public domain

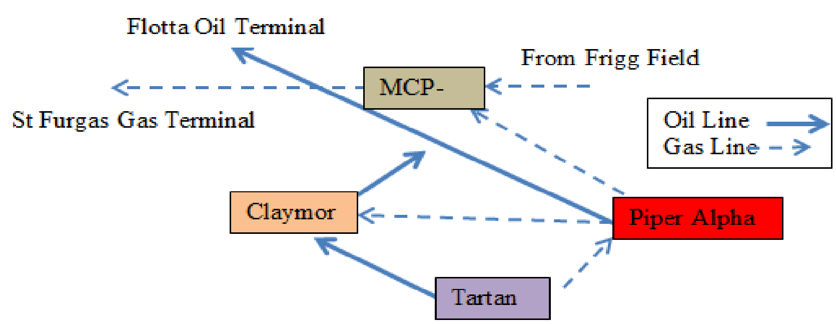
Table 2.9 maps all the causative factors of the NASA Columbia disaster in terms of the five high reliability organisation principles. Again, each column represents an HRO principle and all the causative factors related with the principle.

Table 2.9: A table that maps the causative factors of NASA Columbia disaster in terms the 5 HRO Principles

Mapping the causative factors of the NASA Columbia disaster in terms the 5 HRO Principles				
Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise
Poor risk management process Poor organisation structure: one person holding three conflicting positions. Insufficient time to prepare for launch Inadequate supply of basic personal protective devices.	Disregarded cues from previous similar occurences. Oversimplified and accepted the risk from foam	Weak decision making	No contingency plan for such occurrence. No emergency response plan for such occurence	

2.6.6 Piper Alpha Disaster (1988)

On the 6th of July 1988, an explosion occurred at Piper Alpha, an offshore oil platform operated by Occidental Petroleum, and located in 474 feet of water in the North Sea, about 120 miles north east of Aberdeen, Scotland (Broadribb, 2014). At the time of the incident, Piper Alpha's production was at 125,000 barrels of oil per day. Piper Alpha had 4 export risers connected to it: the Flotta oil terminal riser; the 30 inch subsea pipeline Occidental Claymore platform riser; the 16 inch Texaco Tartan riser; and 18 the inch Total MCP-01 gas processing platform riser.



Piper Alpha's interconnections with other platforms Agwu Agwu April 3, 2018

Fig 2.18 – Piper Alpha's interconnections with other platforms

A gas leak from a blind flange at high pressure resulted in an explosion, killing 165 people on the platform and 2 rescue crews from a standby vessel for a mobile offshore drilling unit nearby (Broadribb, 2014).

Investigations (Cullen Report, 1990) revealed that the incident was caused by a mixture of actions and inactions of organisations and individuals within the organisation. One of 2 condensate pumps (Pump A) was taken out for maintenance, and the open pipe was closed with a blind flange, but was either not properly tightened, or a blind flange of the incorrect rating was used. The maintenance was not completed at close of shift, and the technician duly noted this on the permit to work, returned the permit to the control room, but reportedly did not inform the night shift. Some divers were working on the platform jacket in the evening, and as a result, the diesel and fire pumps were on left on manual. Later that night, Pump B failed and as was the practice, Pump A was started, with no knowledge that the maintenance on it had not been completed. Gas leaked out from the blind flange and formed a gas cloud, leading to a subsequent explosion that destroyed the firewalls, creating secondary fires that kept escalating within a short time. Most ranking supervisors and managers were killed in the initial explosion, and as such, there were limited evacuation instructions or communications with the crew, and with the neighbouring platforms.

The neighbouring Tartan and Claymore platforms did not receive any communication from Piper Alpha, and therefore continued to pump oil into the pipeline, further fuelling the already escalating. They knew they should shutdown considering the level of explosions they could see and hear from Piper Alpha. They did not act based on their expertise, rather, waited for shutdown instructions from their respective hierarchical management. They continued to pump into the pipeline, further fuelling the explosion and massively escalating the disaster.

The Cullen report (1990) determined that the operator's inadequate maintenance and safety practices were the major contributory factors to the initiation and escalation of the incident. It was highly critical of the breakdown in the chain of command, and in leadership communication with the crew. There were also issues around plant designs and management of change. Blast walls were not designed into the process when Piper Alpha was upgraded to handle gas. A new hazard (gas) was introduced into the process without a proper risk assessment and mitigating process to contain the new hazard source. The blast walls could have contained the initial explosion and prevented escalation. Furthermore, the shift handover process was deemed ineffective. The technician left site without properly handing over the details the job done and the scope of remaining work. The new shift on the hand resumed without properly going through the records to see if there were some outstanding work before assuming control. With a proper permit to work system and shift handover system, the initial blast could have been prevented. Finally, the report considered the emergency response process ineffective. This includes the incident escalation process, the evacuation process, the escape systems, and the rescue systems.

In conclusion, it is also clear that the disaster could have been avoided with mindful actions by the organisations involved and by the individuals within these organisations.

Table 2.10 maps all the causative factors of the Piper Alpha disaster in terms of the five high reliability organisation principles. Again, each column represents an HRO principle and all the causative factors related with the principle.

Table 2.10: A table that maps the causative factors of Piper Alpha disaster in terms the 5 HRO Principles

Mapping the causative factors of the Piper Alpha disaster in terms the 5 HRO Principles				
Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise
Inadequate plant design. Inadequate change management process. Inadequate hazard assessment. Inadequate maintenance procedures. Inadequate safety procedures. Inadequate permit to work system. Inadequate shift handover process.		Poor shift handover Inadequate attention to permit process	Ineffective emergency response procedure	Neighbouring plants waited on hierarchy for shutdown instructions, inadvertently fueling the explosion.

2.6.7 BP Texas City Incident (2005)

The BP Texas city incident of March 23rd 2005 led to the death of 15 people, injuring 170 people (Labib & Read, 2013). The incident happened at BP's Texas City oil refinery, considered the 3rd largest refinery in the United States, and BP's largest and most complex refineries with production levels up to 11 million gallons of gasoline per day and a having a rated capacity of 460,000 barrels per day. During normal operations, while an isomerization process unit was in the process of starting up, there was a loss of containment of liquid hydrocarbon, which resulted in a vapour cloud that led to the explosion. The raffinate splitter had been shut down for about a month for maintenance and was in the process of being restarted. After nitrogen purging and pressure testing, cold feed was reintroduced to establish feed drum and column levels. As normal operation commenced, the flammable hydrocarbon was continuously pumped into the raffinate splitter tower for separation into light and heavy hydrocarbons. The level indicator either failed or the operator inadvertently continued filling the distillation column for over 3 hours, much longer than the procedure required, until it began to overflow. The air gas mixture moved at a pressure of about 64 psi and passed through the 21 psi rated safety relief valves which expectedly popped open, allowing the mixture to flow to the blow down drum and stack. From here, the mixture was released into the atmosphere where it caused a gas cloud build up and eventual explosion. Figure 2.19 show the process flow at Texas City isomerization process unit.

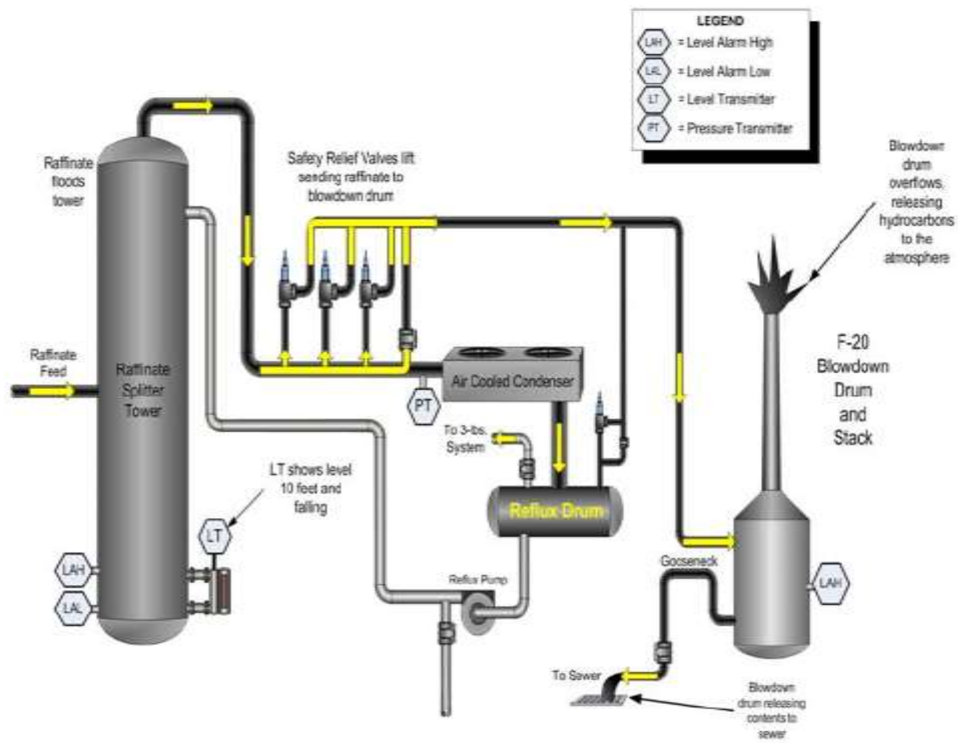


Figure 2.19 – Diagram showing the process flow at the Texas City refinery leading to the 2005 incident. Diagram by US CSB (2007) for CC public domain

Investigations (US CSB, 2005) revealed the causative factors to be employee actions or inactions that led to loss of containment. Some of the actions and inactions include deviations from operating procedures, inadequate supervision, unclear chain of command, ambiguity in roles and responsibilities, inadequate emergency response practices, inadequate hazard identification, inadequate communication, and plant design and engineering problems.

According to Labib & Read (2013), there had been previous events such as leaks, vapour releases, and fires involving the isomerization process unit in the past, but these events were not taken seriously, nor were learning from them used to improve the process. In this instance, the initial causative factor was an operator error of inadvertently over filling the distillation column. This column was designed for a relatively low level in the distillation column. With the overflow, a mixture of hydrocarbon liquid and gas flowed out of the gas line at the top of the distillation column, through the emergency overflow piping, and vented hundreds of feet away. The hydrocarbon vapour, in the presence of oxygen, presented an explosive air-gas mixture that was ignited by a truck engine left idling in the area.

Figure 2.20 – Photo showing the aftermath of the 2005 explosion at BP Texas City refinery. Photo by US CSB (2012) for CC public domain

The final report (BP, 2005; Labib & Read, 2013) also considered organisational and personnel errors as the primary causative factors for the incident. First, the loss of containment was as a result of operator error in overfilling the unit. Secondly, if there was a provision within the design to shut off or recycle the flow, or reduce the base temperature if the level exceeds a certain level, the disaster could have been averted. Thirdly, the operators did not follow specified procedures, neither was there adequate supervision during the start-up, resulting in overfilling the unit, a delayed start-up of the unit, wrong start-up sequence, and a start-up at higher temperature that is specified. In addition to this, communication and adequate control of work in adjacent vicinity was inadequate. The unit was wrongly not considered hazardous in earlier designs and as such, people working nearby were neither warned of the start-up process and the impending danger when the loss of containment occurred. Furthermore, the emergency response process was ineffective. The emergency alarms were not activated in time, and people working in trailers within the vicinity of the unit were neither warned nor evacuated when the loss of containment occurred, increasing the severity of the incident. Finally, although the unit was not tied to the relief flare system at design, there had been several modifications to the process design with no corresponding modification to the flare system. According to Mogford (2005), introducing a relief flare system would have burnt off the hydrocarbon vapour leading to a much reduced impact of the incident. In summary, like the disasters before it, the Texas City incident was also as a result of the actions and inactions of organisations and individuals within the organisation.

Table 2.11 maps all the causative factors of the Texas City disaster in terms of the five high reliability organisation principles. Again, each column represents an HRO principle and all the causative factors related with the principle.

Table 2.11: A table that maps the causative factors of Texas City disaster in terms the 5 HRO Principles

Mapping the causative factors of the Texas City disaster in terms the 5 HRO Principles				
Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise
Inadequate hazard identification and assessment. Poor plant engineering and design. There should have been a shut off or recycle flow process at high temperatures. Plant modification with no corresponding hazard assessment.	Disregarded cues of possible reoccurence based on similar occurences in the past.	Deviation from operating procedures. Poor supervision. Unclear chain of command Ambigous roles and responsibilities. Poor communication. Inadequate training	Inadequate emergency response practices. Emergency alarms not activated in time	

2.6.8 BP Deepwater Horizon Incident (2010)

The BP Deep water horizon incident is another disaster that demonstrates the influence of human and organisational causative factors in disasters. On April 20 2010, an explosion destroyed the BP Deepwater Horizon drilling rig in the Northern Gulf of Mexico, resulting in 11 fatalities and 17 injuries, and leading to a spill of over 4.9 million barrels of crude oil, the largest marine oil spill in the history of the petroleum industry (Guard, 2011). The spill caused extensive damage to aquatic and wildlife habitats with heavy impact on fishing, sea transport, and tourism. The public images of the BP and that of its partners such as Halliburton and Transocean were tarnished. As at 2013, BP had lost US$42.2 billion in criminal and civil settlements and payments (Fontevecchia, 2013)

Figure 2.21 – Picture showing Deepwater Horizon offshore production unit on fire. Photo by US Coast Guard (2010) for CC public domain

The drilling rig had resumed drilling the Macondo well in the seafloor at a depth of about 8000 feet. High pressure methane gas from the well expanded into the drilling riser and rose into the drilling rig. Investigations (Labib, 2014) have shown that the hydrocarbon was released through poorly designed cement barriers that had been earlier cast to isolate the well. The hydrocarbon gas mixed with mud with a resultant increased pressure that damaged the gasket inside the blowout preventer. The blowout preventer is designed to seal off a well in case of, or to prevent over pressure. With the blowout preventer gasket damaged, large quantities of oil, gas, and mud flowed up the rig unto the rig surface leading to the initial explosion. This initial explosion damaged the cables that link the blowout preventer to the control room, thereby reducing the likelihood of initial intervention. The hydrocarbon leak continued, spilling into the engine room and triggering a second and more massive explosion.

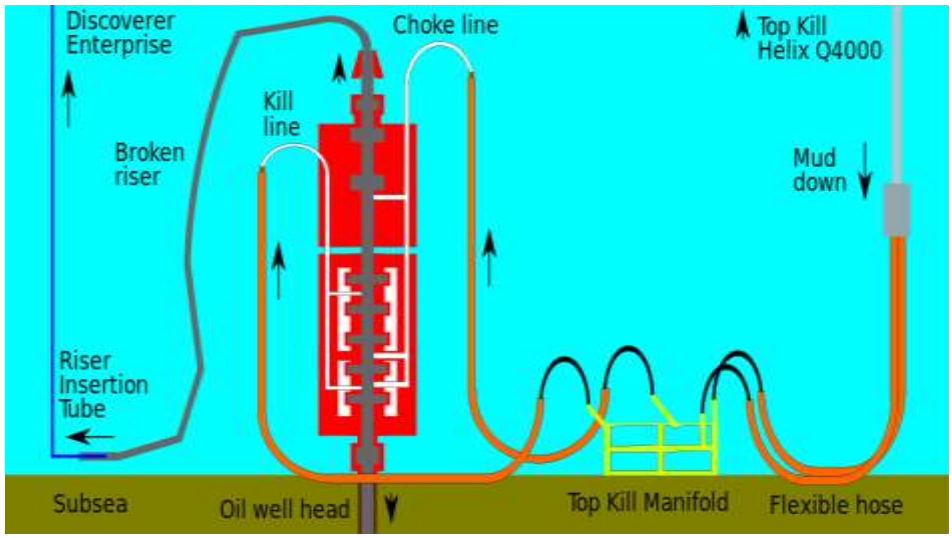


Figure 2.22 – A schematic illustration of a subsea blowout preventer stack installed on a seabed. Diagram by 84user for CC public domain

The On Scene Coordinator report (Guard, 2011) summarized the magnitude of the disaster by the amount of resources committed to the clean up between April 20th 2010 and January 31st 2011 and its impacts. According to the report, "*on a single most demanding day of the response, over 6000 vessels, 82 helicopters and 20 fixed wing aircraft and over 47,849 personnel/responders were assigned; 88,522 square miles of fisheries were closed; 168 visibly oiled wildlife were collected; 3,795,985 feet of containment boom was deployed; 26 controlled insitu burns were conducted, burning 59,550 barrels of oil; 181 miles of shoreline were heavily to moderately oiled; 68,530 gallons (1632 barrels) of dispersant were applied, and 27,097 barrels of oil removed".*

Reports on the 2010 BP Deep water horizon incident also indicates that human factors such as poor design, poor maintenance of safety systems, failure to interpret a failure test, delay in reacting to signals, poor communication, inadequate training, and management issues contributed to the disaster. Labib (2014), citing a DSHP report on the investigations into the Macondo well blowout, considered poor design of cement barrier as the main cause of the blowout. To compound the error of poor design, the cement barrier was not function tested to confirm its suitability to withstand the pressures. Secondly, poor maintenance practices at Deepwater Horizon meant that the fire and gas systems did not work when they were expected to do so. This system could have prevented the explosion. In addition to this, the emergency response management process was ineffective. The safety alarms were non-functional, the crews were not properly coordinated, and most of the crew had no clue what was going on. When it eventually became clear what was going on, most members of the crew were not sure how to respond: some wanted to jump into the sea, while others wanted to wait for the lifeboats. The lifeboats were not adequate for the number of personnel: only two lifeboats were ready, and even then, they were only partially full. The report further blamed BP and its partners for a series of cost cutting decisions that culminated in the compromise of process safety. In all, human and organisational causative factors contributed to the initiation and escalation of the disaster.

Table 2.12 maps all the causative factors of the Deepwater Horizon disaster in terms of the five high reliability organisation principles. Again, each column represents an HRO principle and all the causative factors related with the principle.

Table 2.12: A table that maps the causative factors of Deepwater Horizon disaster in terms the 5 HRO Principles

Mapping the causative factors of the Deepwater Horizon disaster in terms the 5 HRO Principles				
Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise
Poorly designed cement barrier Poor maintenance procedures. No function test of cement barriers. No function test of safety safety systems. Non functional safety alarms.		Failure to interprete a safety test. Poor communication Inadequate training Poor maintenance practices. Poor crew coordination.	Delay in reacting to signals Inadequate emergency response training. Inadequate supply of lifeboats Poor mustering process	

2.6.9 Chapter Summary

The Rio-Paris Flight 447 (Moura et al, 2016), the 2011 Fukushima nuclear disaster (Labib & Harris, 2014), and the 2000 Concorde crash (Labib, 2014) all share similar characteristics of the significance of avoidable causative factors.

Some studies have also shown that the effects of natural disasters could be mitigated through human actions. For instance, a modelling exercise conducted by the U.S. Army Corps of Engineers on Hurricane Katrina (Anderson, 2007) shows that 2 out of every 3 deaths in the Hurricane were due to levee and floodwall failure, and therefore could have been avoided. Rogers et al. (2015) supported this claim and concluded that the flooding during the hurricane Katrina "could have been prevented had the corps retained an external review board to double-check its flood-wall designs." In a bid to cut cost, the U.S. Army Corps of Engineers, the designers of the flood control system and builders, had made a decision to use shorter steel sheet pilings. This, with the benefit of hindsight proved flawed and contributed to the levee and floodwall failure, leading to deaths of hundreds of people. The emergency response process was also considered flawed and the fallout led to the resignation of key personnel in the Federal Emergency management Agency, including their director, and the New Orleans Police Superintendent. Political leaders, most notably the then Mayor or New Orleans, the then Governor, and the then President of the United States were criticized for their inadequate response to the emergency.

In some cases, the organisations, agencies, institutions, and individuals involved in the disasters could not recover from the social, political, and financial impact of these disasters. In some other cases, the organisations, agencies, institutions, and individuals withstood the impacts and evolved to become stronger and more competitive. Understanding the differences between these two categories of organisations, agencies, institutions, and individuals and how they are able to design their processes to withstand the vagaries of operations and remain competitive forms the basis for studying high reliability organisations.

The next two sections shall set the stage for developing the measurement standards by discussing some literatures around the concepts of benchmarking and maturity models.

2.7 Benchmarking

Benchmarking is considered as one of the most successful processes of assessment and continuous improvement (Tasopoulou & Tsiotras, 2017). Vlăsceanu et al. (2004) defines benchmarking as a standardized method for collecting and reporting critical operational data in a way that enables relevant comparisons among the performances of different organisations or programmes, usually with a view to establishing good practice, diagnosing problems in performance, and identifying areas of strength. Similarly, Blackstock et al. (2012) defines it as the "process of self-evaluation and self-improvement through the systematic and collaborative comparison of practice and performance with similar organisations in order to identify strengths and weaknesses, to learn to adapt and to set new targets to improve performance". Benchmarking compares actual and planned practices to those of comparable organisations in order to identify best practices, generate improvement ideas, and generate a basis for performance measurement (Invernizzi et al, 2017)

A comparable Japanese work for benchmarking is *"dantotsu"*, which literally means: the best way to be the best of the best. It is therefore a practical tool that aids users to learn from best practices and processes, with a view to improving their own practices and procedures, and possibly surpass those best practices and procedures. It helps users examine how others have achieved their performance levels and to understand the processes the adopted with a view to business improvement.

There is no universally accepted process for benchmarking. Camp (1989) developed a 12 step approach to benchmarking. This includes the selection of the subject; definition of the process; identification of potential partners; identification of the data source; and collection of data and selection of partners. The other stages include the determination of the gap, establishment of the process differences, targeting future performance, communication, adjustment of goals, implementation, and review. This has been refined by different organisations to suit their needs. In all, most benchmarking processes occur in three stages:

- The diagnostic stage: where the performance metrics are compared with other organisations to identify gaps and organisations to learn from.
- The analysis stage: where the practices behind the numbers are evaluated
- Implementation stage: where the best practices are implemented

A more detailed benchmarking process step would be divided into planning, evaluation, integration, implementation, and maturity stages. The planning stage is normally a painstaking stage as any errors here would potentially negate the intent of the benchmarking exercise. During the planning stage, the organisation is expected to:

- Identify what is to be benchmarked
- Identify comparative companies
- Determine data collection methods
- Collect relevant data

The evaluation stage involves going over all the data collected during planning, as well as the reasons for the better outcome of the benchmarked processes. The organisation would thereafter set goals in line with benchmarked processes. During the evaluation stage, the organisation is expected to:

- Perform a gap assessment and identify performance gaps
- Identify potential performance projections

The evaluation stage would be followed by the integration stage where the organisation would:

- Communicate benchmark findings among relevant stakeholders
- Gain acceptance from the stakeholders
- Establish functional goals.

As soon as the functional goals are established, the next stage would be to implement. During implementation, the organisation would be expected to:

- Develop action plans with all the factors involved such as time line, responsible owners, and targets.

- Implement agreed actions. During implementation, management buy-in is critical, and as such, senior management would normally drive the coordination of activities, monitor implementation progress, and act promptly to de-bottleneck the implementation process.
- Use feedback from the results to improve the benchmarks.

There are generally three types of benchmarking. Internal benchmarking involves comparing different business units, operating units, or departments against a standard the organisation has set for itself. Competitor benchmarking involves benchmarking against other organisations within the same industry that are in direct competition, such as where Google benchmarks against Yahoo; Apple against Microsoft; or University of Portsmouth against University of Southampton. External benchmarking, also regarded as "Best in Class" benchmarking involves benchmarking an organisation against other organisations both within and outside their industry, that are considered to be at the highest level in the indicators being benchmarked against. An example would be manufacturing company benchmarking its safety standard against Lufthansa Airlines, if Lufthansa is considered a "best in class" in safety.

Despite the obvious advantages of benchmarking, there are a few pitfalls that practitioners should bear in mind before adopting the process. First, there is no guarantee that the performance indicators used to improve one organisation would be appropriate in another organisation. Secondly, poor definition and planning could potentially render the benchmarking process useless with results that irrelevant. Poor planning might also develop performance indicators that are not fit for purpose, or would lead to incorrect comparisons. They might be indicators that are not properly aligned with the business process, and would therefore be counterproductive, or a waste of resources and man-hours. Finally, implementing a benchmarking exercise without establishing a baseline would make it impossible for the organisation to know when the processes are improving. A careful and mindful implementation of the benchmarking process however would ultimately lead to organisational maturity. Organisational maturity would be discussed in the next section.

2.8 Maturity Models

Researchers have studied organisations' maturity levels as a way of improving performance. De Bruin & Rosemann (2005) defined a maturity model as "a measure to evaluate the capabilities of an organisation in regards to a certain discipline". It is a framework that describes a methodical progression through successive stages of maturity with incremental maturity behaviours, towards the desired maturity behaviours. It helps organisations identify their current status in terms of the subject being reviewed, identify where similar organisations are in terms of the same subject and benchmark themselves against acceptable standards, often the best in class. It describes a gradual path to sustain the status or progress to a desired maturity level, with a view to optimizing continuous performance improvement. It allows for individuals and organisational internal interdepartmental and external assessments, to self-assess the state of maturity of various aspects of their processes against benchmarks (Neuhauser, 2004), with a view to optimizing continuous performance improvement (Demir & Kocabas, 2010).

Maturity models attempt to systematise certain processes prevalent in organisations considered as mature, and describe precise criteria for attaining and progressing through different maturity levels. Maturity models describe expected behaviour for each level and the behaviour usually improves towards the desired behaviour as the maturity level increases. For an organisation trying to implement a maturity model, the first step would normally be for it to establish its current status. It would then perform a gap assessment to determine the variance between its current maturity level and the desired. Once the gap is determined, the organisation would progressively perform specific actions to close the gap and attain its desired maturity level. Afterwards, it would continuously perform specific actions to ensure the sustainability of the attained maturity level.

Some researchers have tried to question the usefulness staged maturity models in organisational improvement. While accepting the usefulness of staged maturity models in large organisations, Huang & Zhang (2010) questioned its usefulness in small and medium scale organisations. They cited conflicts with business operations, cost overruns, poor implementation by consultants, absence of specialized personnel, and inefficient alignment of the model with business goals as key bottlenecks faced by small and medium scaled organisations during the implementation of staged maturity models. Beadell (2009) questioned the usefulness of a staged maturity model in an engineer’s job performance and job satisfaction. He also questioned the embedded theories and the extent to which they exploit the negative effects of the organisation with respect to the worker. Uskarci & Demirors (2017) also questioned the continuity, extent, and participation characteristics of staged maturity models. They analysed the software process improvement activities and employee perception within 2 different software companies on maturity level 3 – the mid-point on most maturity models. They concluded that despite the usefulness of the maturity model, there were short comings with respect to organisation wide continuous improvement. The implementation was heavily influenced by the quality and motivation levels of the personnel, as well as their roles within the organisational hierarchy. They therefore argue that although staged maturity models are key to organisational improvement, the contribution of employees during implementation could potentially derail the process and erode the potential process improvement gains. In all these arguments, one thread is common: the effectiveness of a staged maturity model directly proportional to the effectiveness of its implementation. This ties closely with the keys to a successful benchmarking exercise as discussed in Section 2.7. Faulty implementation would negate the aims of adopting the model.

Research indicates that organisations with higher maturity levels are expected to be successful in terms of effectiveness and efficiency; thus they have a competitive advantage in the marketplace (Backlund et al, 2014; Nikkhou et al, 2016). According to a UK Office of Government Commerce publication in 2010, more mature organisations have experienced an 85% reduction in defects and a 75% reduction in cost (Nikkhou et al, 2016).

Most of the works on maturity models were adapted from Crosby's (1979) work on quality management. The purpose of the maturity model was to provide a roadmap for organisations on their march towards a formalized quality improvement programme. Crosby (1979) developed a quality management maturity model (Table 2.13) that mapped organisations into five maturity stages: stage 1 - *Uncertainty, stage 2 - Awakening, stage 3 - Enlightenment, stage 4 - Wisdom*, and stage 5 – *Certainty*, with *uncertainty* being the lowest and *certainty* being the highest. To him, the higher an organisation is on the maturity grid, the better the product quality. For each level, categories of dimensions were assigned. These include: management understanding and attitude; quality organisation status; problem handling; cost of quality as a percentage of sales; quality improvement actions; and summary of company quality posture. For immature organisations in level 1, Crosby maintained that product quality was at the lowest with poor management understanding of the issues surrounding quality. These issues improved as the organisation moved up the maturity grid

Table 2.13 - Crosby's quality management maturity model showing the five stages of maturity mapped against quality management dimensions. Adapted from Crosby (1979)

	Stage 1: Uncertainty	**Stage 2: Awakening**	**Stage 3: Enlightenment**	**Stage 4: Wisdom**	**Stage 5: Certainty**
Management Understanding	No comprehension of quality as a management tool. Tend to blame quality department for "quality problems".	Recognising that quality management may be of value but not willing to provide money or time to make it all happen.	While going through quality improvement programme learn more about quality management; becoming supportive and helpful	Participating. Understand absolutes of quality management. Recognise their personal role in continuing emphasis.	Consider quality management as an essential part of company system
Quality organisation status	Quality is hidden in manufacturing or engineering departments. Inspection probably not part of organisation. Emphasis on appraisal and sorting.	A stronger quality leader is appointed but main emphasis is still on appraisal and moving the product. Still part of manufacturing or other.	Quality department reports to top management, all appraisal is incorporated and manager has role in management of company.	Quality manager is an officer of company; effective status reporting and preventive action. Involved with customer affairs and special assignments.	Quality manager on board of directors. Prevention is main concern. Quality is a thought leader.
Problem handling	Problems are fought as they occur; no resolution; inadequate definition; lots of yelling and accusations.	Teams are set up to attack major problems. Long-range solutions are not solicited.	Corrective action communication established. Problems are faced openly and resolved in an orderly way.	Problems are identified early in their development. All functions are open to suggestion and improvement.	Except in the most usual cases, problems are prevented.
Cost of quality as % of sales	Reported: Unknown	Reported: 3%	Reported: 8%	Reported: 6.5%	Reported: 2.5%
	Actual: 20%	Actual: 18%	Actual: 12%	Actual: 8%	Actual: 2.5%
Quality improvement actions	No organised activities. No understanding of such activities	Trying obvious "motivational" short-range efforts.	Implementation of a multi-step programme (e.g. Crosby's 14-step) with thorough understanding and establishment of each step.	Continuing the multi-step programme and starting other pro-active / preventive product quality initiatives.	Quality improvement is a normal and continued activity.
Summary of company quality posture	"We don't know why we have problems with quality".	"Is it absolutely necessary to always have problems with quality?"	"Through management commitment and quality improvement we are identifying and resolving our problems."	"Defect prevention is a routine part of our operation."	"We know why we do not have problems with quality."

Crosby's research led to the development of maturity grids for different management fields. Introna et al (2014) proposed the energy management maturity model. They structured it much like Crosby's quality management maturity model with 5 stages: stage 1- *initial, stage 2 - occasional, stage 3 - planning, stage 4 - managerial, and stage 5 - optimal.* Nikkhou et al (2016) developed the portfolio management maturity model using the same model developed by Crosby. They also recognized 5 increasing maturity levels of *recognition, forming, dynamism, wisdom, and property.*

Using Crosby's model, Antil (1991) and later Fernandez et al (2003) and Oliveira et al (2012) modified the quality management maturity model and adapted it to suit maintenance management body of knowledge. They focused the categories of dimension to reflect management understanding and attitude; problem handling; company maintenance posture; and computerized maintenance management systems.

Table 2.14 - Maintenance management maturity model showing the five maturity stages mapped against four maintenance dimensions. Adapted from Fernandez et al (2003)

	Stage 1: Uncertainty	**Stage 2: Awakening**	**Stage 3: Enlightenmen**	**Stage 4: Wisdom**	**Stage 5: Certainty**
Management understanding & attitude	No comprehension of maintenance as a management tool	Recognition that maintenance management may be of value	Learn more about maintenance management: becomes supportive	Participative and recognised its role	Maintenance is an essential part of the company system
Problem handling	Problems are fought as they occur	Still reactive but with spare parts available when failures occur	Problems solved by input from maintenance, operations, engineering and quality control	Predictive using monitoring techniques	Problems are prevented increasing availability and therefore productivity
Company maintenance posture	"We don't know why we have problems in maintenance"	"Is it necessary to have problems with maintenance?"	"We identify and solve problems"	"Quality products cannot be made with poorly maintained equipment, therefore quality maintenance is a routine"	"We don't expect breakdown, on the contrary, we are surprised when they occur"
CMMS	No CMMS used	System contains asset and materials management modules	A condition monitoring event module is integrated into the system	Capable to generate PM schedules. A DSS is used to support the decision making process	Fully ausomated. From the detection of failure to the generating of work orders based on meaningful and reliable information.

The maturity level of each maintenance organisations would determine the maintenance strategies adopted. For instance, Oliveira (2012) showed that whereas lower maturity organisations deployed only corrective maintenance, had no computerized maintenance management system, used no key performance indicators, and had no management models in place; medium organisation progressed to a combination of corrective and preventive maintenance, used few simple key performance indicators and generic computerized maintenance management systems, and adopted some form of total productive maintenance. The more mature organisations on the other hand deployed predictive maintenance, used specialised key performance indicators, customised computerized maintenance management systems, and deployed a number of management models like total productive maintenance, reliability cantered maintenance, and maintenance engineering. Oliveira (2012) also observed that mature organisations are characterised by the systematic and standardized way they conduct their business. They act and achieve their objectives consistently irrespective of which personnel is on duty, and irrespective of the individual differences of personnel. Immature organisations on the other hand rely on the heroic and often-spontaneous approaches of individuals, who depend on their often-biased individual experiences and often times lose their targets by wide margins of error. Understanding these would therefore help the organisation to deploy improvement resources optimally.

Other maturity models include the maturity model for production management (Kosieradzka, 2017), safety culture maturity model (Fleming, 2000), Capability Maturity Model (CMM); Capability Maturity Model Integration (CMMI); Modelling Maturity Levels (MML); and Organisational Project Management Maturity Model (OPM3).

This research leveraged Crosby's model (table 2.19), and the maintenance management maturity model (table 2.20) to develop its maturity model, the Organisational Reliability Maturity Model (ORM^2) but with focus on organisational reliability dimension. The research sees a close relationship between quality, maintenance, and reliability management and therefore developed its maturity model to mirror these two models. Furthermore, the models discussed earlier mostly follow a similar structure of mapping the maturity models against their own individual dimensions. This research utilised the same five maturity levels as used by Crosby (1979), Antil (1991), and Fernandez et al

(2003) and Oliveira (2012), but mapped them against the five principles of high reliability organisation theory instead of the quality dimensions used by Crosby (1979, or maintenance dimensions used by Antil (1991), and Fernandez et al (2003) and Oliveira (2012). It also moved a little bit away from Crosby's choice of terms for the maturity levels, choosing instead five terms "*Silent", "Starter", "Stable", "Sustain", and "Summit"*. These words are simplistic and are used in an alliterative manner to enhance visibility and usability. This research believes that it would be easier to visualize and remember these words than the terms "*Uncertainty*, *Awakening*, *Enlightenment*, *Wisdom, and Certainty*", all of which could require further literature reviews to fully understand. Finally, by referring to this model as the *"5S Model",* this research hopes to enhance visualization and comprehension, and hopefully connect better with the potential users. The model would be discussed in more details in chapter five.

2.9 Chapter Summary

This chapter has identified and discussed some relevant literature that helped to shape the research. The research had set out to investigate the extent to which the mindfulness of organisations could be measured, as well as the ability of these measurements to help improve the maturity of organisations. The research tried to argue that most disasters are resultant effects of the lack of mindfulness in organisations, and that for disasters to be prevented, the mindfulness of organisations must first be improved. This chapter therefore discussed 7 of the world's worst disasters to gain a perspective on how they happened, the circumstances that led to the disasters, and the mindful actions that could have prevented their occurrence.

The chapter started with the circumstances surrounding the Titanic sinking in 1912 and attributed the causative factors to human and lack of organisational mindfulness. It further discussed the Bhopal disaster of 1984; the Chernobyl nuclear disaster of 1986; the 1986 explosion of NASA's Challenger; the 2003 explosion of NASA's space shuttle, the Columbia; the 1988 Piper Alpha disaster; the 2005 BP Texas City refinery disaster; and the 2010 BP Deep water Horizon disaster. In each of the incidents, the research tied the causative factors to organisational and human influences. In addition to these disasters the chapter also described a few natural disasters and argued in favour of human and organisational influences in reducing the impacts of the natural disasters. It argues for instance that casualties of hurricane Katrina could have been tremendously reduced by the mindful behaviours of the responsible people before during and after the hurricane.

The chapter described 8 different perspectives about the causative factors of disasters. These perspectives include the Normal accident theory as described by Perrow in 1984; Turner's man-made disaster model; the energy and barrier model; the conflicting objectives theory; defence-in-depth model; inherently safer design model; the principles of resilient engineering; and the high reliability organisation theory. It each perspective, the chapter tries to show how it relates or differs from some other perspectives, as well as how the perspective ties into the research's perspectives.

Finally, the chapter described literatures surrounding the concepts of mindfulness, benchmarking, and maturity models. These are all key concepts that will recur for the duration of the research and therefore their meanings with respect to the research had to be explained.

Chapter 3 will describe the methods and methodologies utilized during the data collection and analysis.

CHAPTER THREE

Methodology

3.1 Introduction

Chapter two has identified and discussed some relevant literature that helped to shape the research. It tried to argue that most disasters are resultant effects of the lack of mindfulness in organisations, and that for disasters to be prevented, the mindfulness of organisations must first be improved. To highlight this, the chapter described seven of the world's worst disasters, and traced their causative factors to lack of individual and organisational mindfulness. It pointed out that the circumstances that led to the disasters could have been avoided through mindful behaviours of the respective social entities within the organisations. In addition to the industrial disasters, it also argued that human and organisational influences could reduce the impacts of the natural disasters such as hurricane Katrina.

The chapter described literatures on different perspectives about the causative factors of disasters, their differences and relationships, as well as how they tie into the perspectives of this research. Finally, the chapter discussed the concepts of mindfulness, benchmarking, and maturity models - all key concepts that helps develop the research.

Chapter three will describe the methods and methodologies utilized during the data collection and analysis process. Crotty (1998) stated that for a research to be considered successful, it must clearly state and explain all the choices it made to arrive at its data. The chapter therefore sets out to explain the choices made in this research; adopting the Saunders' research onion (Saunders et al, 2016) as a theoretical lens. The onion (figure 3.1) depicts the factors underlying the choice of data collection techniques and analysis methods. It has five outer layers that must first be peeled open, understood and explained, before the method of data collection and analysis that resides at its core can be understood. These five outer layers include the research philosophy, the approach to theory development, methodological choice, research strategies, and the time horizons. The research onion is a very useful tool due to its adaptability for most research methodologies and varying contexts (Bryman, 2016).

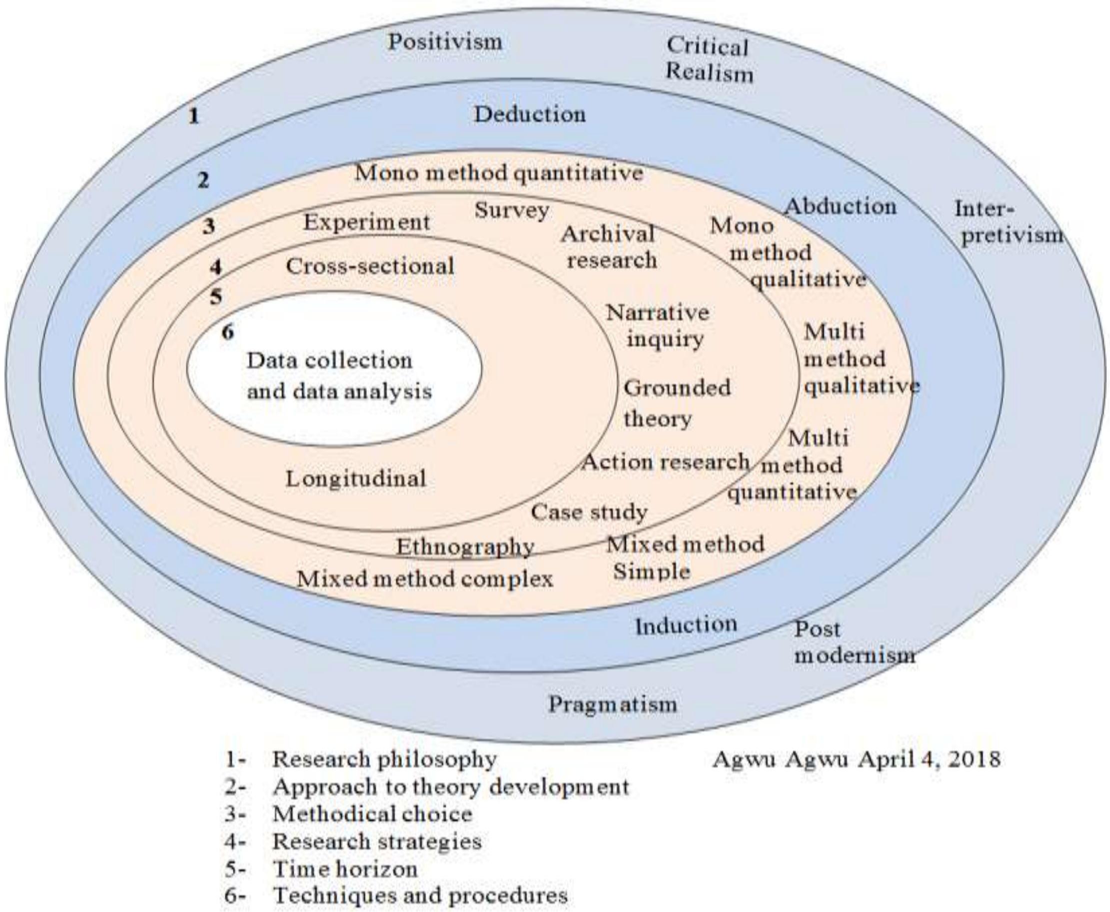


Fig 3.1: Research onion depicting the factors underlying the choice of data collection techniques and analysis methods. Adapted from Saunders et al. (2016)

Using the onions, this chapter describes the data gathering process and discusses the rationale behind the choices and assumptions made during the data gathering process. It starts by examining the various philosophical underpinning, and the approaches to theory development behind this research. It explains and justifies the assumptions and rationale behind these philosophical choices in relation the myriad of alternatives available. It then delves into the research design, where it discusses the various choices and strategies involved. Furthermore, it describes the research sampling techniques and processes; data collection techniques and processes; issues around reliability and validity; as well as the research limitations. Finally, it narrates all the ethical considerations made in the course of the research.

The next section shall describe different research philosophies in academic research. It shall highlight the philosophy adopted by this research and provide justifications for the adopting some philosophies over others.

3.2 Research Philosophy

3.2.1 Introduction to Research Philosophy

Research philosophies are the set of beliefs concerning the nature of the reality being researched (Bryman, 2016), and they justify how researches are carried out (Flick, 2015). The usefulness or otherwise of understanding research philosophies and adopting one philosophy over another has been an ongoing debate among scholars (Knudsen, 2002; Mkansi & Acheampong, 2012; Saunders et al, 2016). This debate has been exacerbated by the apparent lack of consensus among the proponents of the classifications and descriptions of the various taxonomies of the research philosophies as used by different scholars.

Among the proponents of understanding and adopting research philosophies, two positions – unificationism and pluralism, have emerged (Knudsen 2003). Unificationists such as Pfeffer (1993) lean heavily on Kuhn (1970) and Polanyi (1958), both of whom argue for the unification of management research under a uniform philosophy, paradigm and methodology. To them, management research could learn from scientific research, which are paradigmatically developed and thus tend to have more structure and a more rapid advancement Knudsen (2002). Pluralists on the other hand believe in the "more the merrier" syndrome. To them, the diversity helps enrich business and management research field (Saunders et al, 2016). Different theories are therefore required to understand complex realities associated with management research, as well as enhance competition. This research therefore tries to avoid the 'specialization trap' (Knudsen (2002) by adopting the pluralism perspective, while keeping focus on the research questions and the limits of the research to avoid straying along the 'fragmentation trap' (Knudsen (2002).

Research philosophies are influenced by philosophical assumptions and these assumptions must be understood to gain clearer insights into how the philosophies contribute to the data collection and analysis process. These assumptions include axiological assumptions, ontological assumptions, and epistemological assumptions. Axiological assumptions refer to values and ethics and will be discussed in more details in section 3.9: Ethical considerations.

Ontological assumptions refer to assumptions a research makes about the nature of reality (Saunders et al, 2016), and clarifies the position of the research on reality. These assumptions determine the view of the research based on the objectivity or subjectivity of its reality (Bogdan & Bilken, 1998; Blaikie, 2007). Whereas objectivism is derived from the natural sciences and views the social reality of the research as external to the social actors, subjectivism is derived from the arts and humanities, and sees the social reality as a function of the actions, perceptions, and nuances of the social actors (Bogdan & Bilken, 1998; Bryman & Cramer, 2001; Hatch & Cunliffe, 2006; Bell & Bryman, 2007; Blaikie, 2007; Bryman, 2016; Saunders et al, 2016)

Given that this research expects to study the behaviour of the organisations as well as the people within the organisations to help apply the high reliability organisations theory towards organisational maturity improvement, it is therefore necessary for the research to combine both objective and subjective assumptions. This research makes objective assumptions based on facts and figures derived from secondary sources and questionnaires. It also uses subjective assumptions derived from the feelings, understandings, perceptions, and nuances of the social players within the organisations, obtained through interviews, to triangulate the objective assumptions.

Epistemological assumptions on the other hand refer to the considerations of what constitute acceptable, valid, and legitimate knowledge (Saunders et al, 2016). They are assumptions about the grounds of knowledge, how to define and separate what is regarded as ‘true’ from what is regarded as ‘false’, and how knowledge might be understood and communicated to others (Burrel & Morgan, 1979; Hassard, 2012; Bryman, 2016). They are assumptions about how to gain the knowledge of reality, how what exists may be known, what can be known, and the criteria that must be fulfilled to describe what is known as knowledge (Blaikie, 2007). These assumptions explore the sources and limits of knowledge, and determine whether knowledge can be acquired or personally experienced (Burrel & Morgan, 1979; Temple & Johnson, 1998). They question the research methods and how knowledge can be produced and validated (Eriksson & Kovalainen, 2015).

This research delves into the multidisciplinary realm of operations and process management, organisational behaviour, human behaviour, and interpersonal relationships. It would therefore be expected that different types of knowledge could be considered legitimate for this research. With a variety of acceptable epistemologies come a wide variety of choice of methods, and the inherent effect those variety of choice of methods could have on the strengths and limitations of the research findings (Saunders et al, 2016). This research agrees with the positivist assumption that objective facts offer the best credibility as they are less open to bias, are easily verifiable and replicable. It also understands that to explore its multidisciplinary concepts of operations and process management, organisational behaviour, human behaviour, and interpersonal relationships, it must be open to exploring other subjectivist assumptions. These subjectivist epistemological assumptions are more likely to offer a rich and complex view of organisational realities, account for the differences in individual contexts and experiences and are therefore better equipped to explore the social realties surrounding the social actors (Saunders et al, 2016). The research therefore used a combination of epistemologies to arrive at its results and conclusions.

Research philosophies are the cornerstones of a research. Although they might view the research goals and the possible roadmap towards achieving these goals differently (Goddard & Melville, 2004), they complement, rather than oppose one another. Their choice is dependent on the type of knowledge under research (May, 2011). The philosophies helped this research to determine the evidence required, how they are gathered and interpreted, and how they would provide answers to the questions under investigation. They helped the research identify early enough, which research design will work or otherwise. They also encouraged creativity and innovations where the design could be beyond the experience of the researcher or where there could be constraints of different subjects or knowledge structures (Easterby-Smith et al, 2012).

The five different philosophies identified by Saunders et al (2016) in the 'research onion', as well as how each is related to and applied by this research will be discussed next. These include positivism, critical realism, interpretivism, post modernism, and pragmatism.

3.2.2 Positivism

Positivism relates to the philosophical position of the natural sciences and views social entities as real, just as natural scientists would view physical objects and natural phenomena (Creswell, 2013; Saunders et al, 2016). It entails working with discrete observable social reality and events that interact in an observable, determined, and regular manner. It would usually lead to statistical analysis and the production of credible and meaningful data (Saunders et al, 2016; Collins, 2010). Positivism holds that "the social world exists externally, and that its properties should be measured through objective methods, rather than being inferred subjectively through sensation, reflection, or intuition" (Easterby-Smith et al, 2012). Positivism relies on data from experiments, samplings, and surveys to objectively interpret reality (Gill & Johnson, 2010) and the product of such research should be "law-like generalizations" akin to physical and natural science. These generalizations become rules and laws that would help explain and predict behaviours and events of social entities and organisations (Saunders et al, 2016).

The researcher adopts a positivist approach through the use of secondary data, as well as through questionnaires. The questionnaires were administered anonymously with the respondents required to select from a list of pre-determined responses without any chance of the researcher influencing the data. This method kept the researcher neutral, detached from the responses, and therefore external to the data collection process - a key element of the positivist philosophy (Saunders et al, 2016; Crotty, 1998). Data from secondary sources such as company publications, financials, and journals, used in this research also fall within the realm of positivism. They are already established facts and could not therefore, be influenced by the researcher. Data obtained from interviews are subjective and do not fall under positivist approach. They could be influenced by a lot of factors such as the respondent's attitude, initial responses that could lead to further follow up questions, and the possible connection or relationship that might develop between the researcher and the respondent. This data could therefore lose its objectivity and would then rely on subjective realities inferred through the feelings, intuitions, experiences or individual world views of the social actors involved.

3.2.3 Critical Realism

Critical realism is a research philosophy in which the researcher strives to be aware of the ways the socio-cultural backgrounds and experiences might influence the research and strives to minimize such biases and enhance objectivity as much as possible (Saunders et al, 2016). Tversky & Kaheman (1974) and Tversky et al (1990) studied how biases and beliefs might influence judgments and decisions. They concluded that subjective decisions and judgments are mostly based on data with limited validity, processed through heuristics – a learning and problem solving approach that employs a practical method not guaranteed to be optimal or perfect, but sufficient for the immediate goals. They described biases based on three heuristics: representativeness, availability, and anchoring; all of which might be highly economical and usually effective, but would often lead to systematic and predictable errors. They are mostly mental shortcuts that ease the cognitive load of decision making.

Critical realism tries to minimize these biases by looking beyond sensations and observations to understand the underlying structures of realities that shape these observable sensations and realities. Critical realism layers ontology into three levels: the real, the actual, and the empirical (Bhaskar, 2008). The 'real' are the mechanisms that generate phenomena at the level of the actual, while the 'empirical' refers to the experiences of the social actors in those events. Critical realism is non –reductionist and does not separate the physical world of causes from the mental world of thoughts (Harre & Bhaskar, 2001). It rather takes a stratified view of the nature of reality, in which the real stratification of being is separate from the knowledge of being (Peters et al, 2013).

It recognizes the existence of multiple levels and modes of engagement that exist between the 'knower and the known' (Norris, 2007).

Whereas the direct realist makes judgments and reality based on the immediate observations, experiences and sensations (Saunders et al, 2016), the critical realist views reality based on 'retroduction' (Reed, 2009), an ability to combine the immediate sensations, experiences and observations with a retrospective mental processing of the circumstances and possible causative factors of those observations, experiences and sensations.

This research adopts the critical realism worldview in its analysis. It assumes the position of Bhaskar (2008) that to understand what is going on in the social world, there need to be an understanding of the social structures that gave rise to the phenomena under research (Saunders, 2016). This research therefore tries to explain the observable behaviour of organisations with respect to their reliability by looking for underlying causative factors and mechanisms through which their social structures shape their daily actions and interactions.

3.2.4 Interpretivism

Interpretivism contrasts directly with the positivist views on observable reality and posits that methods of the natural sciences are inadequate for conducting research within the domain of social science (Tsang, 2014). This contrast stems from the fact that whereas the natural sciences try to explain unintentional phenomena, social sciences focus on intentional phenomena by trying to interpret the meanings behind the actions and interactions of the social actors (Schutz, 1970). Interpretivism stems from the view that reality is neither objective nor exterior but is socially constructed and given meaning by people. It sees humans as social actors, interpreting social roles in relation to their perceived meanings at each time, (Willian, 2000). Interpretivism understands that different social actors with different experiences, orientations and cultural backgrounds would infer different meanings to different circumstances and therefore would create and experience different social realities. It therefore progresses through data gathering from which ideas are induced and generalized, often through theoretical abstraction (Saunders et al, 2016).

This research relied on the interpretivist mind set and tries to capture as diverse social actors as possible. It researched a diverse array of employees with different cultural backgrounds, different experience levels, different job levels, and different industries so as to get a balanced view of the different realities prevalent within the organisation. For instance, when confronted with a question on how the '*managers constantly monitor day to day activities'*, the responses were sharply divided along the line of years of experience and position within the organisation. On the one hand, the managers were contented in their belief that they were constantly monitoring the day to day activities of their teams. On the other hand, most of the mid-level employees and older supervisors believed they were being micro-managed by the managers, and were not happy about it. The younger supervisors and some lower level employees viewed the constant monitoring as positive and relished the chance to interface with their managers. By studying the diverse social realities from the diverse perspectives of these social actors, this research tries to gain new and richer understanding and interpretations of the complexities of the social actors within the organisations.

3.2.5 Postmodernism

Postmodernism seeks to expose and question the power of relations that creates and sustains dominant realities (Calas & Smircich, 1997). It argues that there is no underlying reality to things, that ‘reality’ is what the current dominant social entities have defined as real (Montagna, 1997). Positivism posits that accepted social realities are functions of the power relations and prevalent ideologies that dominate the particular contexts. It tries to deconstruct these realities to identify and make visible the instabilities within their widely accepted truths, as well as other realities those truths may have failed to take into consideration or left silent (Saunders et al, 2016). It argues that for each currently accepted reality, there are as many meanings as there are interpretations of them, and therefore that all discourses are rhetorical (Montagna, 1997).

Just like history is said to be written by the victors to suit their own narrative, and may therefore not be a true account of the actual events, the accepted social realities may not necessarily be the best. These accepted social realities are just perceived, at that instant, as the collective choice based on the power relations and ideologies that dominate the particular context (Saunders et al, 2016). The other latent realities could create alternative realities and truths, and could become the accepted realities should the dominant ideologies and social players change. The main goal of postmodernism is to challenge the established ways of thinking and knowing (Kilduff & Mehra, 1997), and to highlight the validity and legitimacy of the suppressed and marginalized ways of thinking and knowing (Chia, 2003).

Proponents of the high reliability organisation theory have long held that only certain named organisations are considered high reliability, and laid out some criteria to justify this classification. A postmodernism world view would therefore challenge this concept and seek to demonstrate what perspectives and realities have been excluded and whose interests the exclusions would serve. Such perspective falls outside the scope of this study, as it seeks to find out how the high reliability organisation theory can be extended to help other organisations become more mature in terms of organisational reliability. Within this context however, the theory has so far tended to favour big organisations with highly coupled and complex technologies. This research therefore borrows from postmodernism to show that smaller organisations with less complexity and less coupling (Perrow 1984) could potentially pose as much danger as the traditional “high reliability organisations’ and as such, should be included as organisations requiring to perform at high reliability.

3.2.6 Pragmatism

Pragmatism as a research philosophy argues that concepts are only relevant when they support action. It considers that research starts with a problem and aims to contribute practical solutions that inform future practice (Saunders et al, 2016). Pragmatism understands that given the diverse ways of understanding and interpreting the world and conducting a research, it would be impossible for a particular point of view to providing a comprehensive appreciation of the entire picture (Saunders et al, 2016). Although most pragmatists use mixed methods for data collection and analysis, pragmatism does not presuppose the use of mixed methods. It rather advocates the use of a method or methods that enable credible, well founded, reliable and relevant data to be collected that advance the research (Armitage, 2007; Kelemen & Rumen, 2008; Saunders et al, 2016). By combining two or more philosophies, the researcher could complement the strengths and weaknesses of the philosophies to produce a research that better answers the research questions (Patton, 1990; Creswell, 2013).

For instance, this research intends to answer the questions:

- To what extent can the reliability of organisations be measured?
- How can these measurements help diverse organisations become more mature?

To answer these questions, the research first delved into the realm of positivism by researching secondary data and through the use of questionnaires to establish objective facts. The questionnaires, administered anonymously, with the responses devoid of researcher influences, were combined with data from secondary sources such as company publications, financials, and published academic journals to establish the objective observable facts. These facts alone could not answer the research questions. It could not capture the subjective realities inferred through the feelings, intuitions, experiences nuances, and individual world views of the social actors involved. A new philosophy was therefore introduced through the use of interviews to help achieve this. Furthermore, an effective answer to the research questions would involve increasing the diversity of the respondents, which falls within the interpretivism world view. Finally, the research tries to explain the observable behaviour of organisations with respect to their reliability by looking for underlying causative factors and mechanisms through which their social structures shape their daily actions and interactions. This falls within the realm of critical realism.

It can therefore be seen that although the research combines different philosophies and methods, it does so only to help provide credible, well founded, reliable, and relevant data that furthers the research objectives and help provide answers to its research questions

To summarise, given that this research expects a balanced insight from the organisations and individuals within the organisations under study, it combines objective and subjective ontologies to obtain facts and figures, as well as understand the feelings, experiences, perceptions, and nuances of the social players within the organisations. From the perspective of epistemology, the research is interdisciplinary in nature. The research has foundations in diverse knowledge areas such as process safety, engineering, reliability, operations management, human resources, sociology, and psychology. Different types of knowledge were therefore considered to be valid and legitimate, and therefore acceptable. Finally, the research takes a pragmatist approach by combining the objectivity of positivism, the subjectivity of interpretivism, and the explanation of the world view of organisations using critical realism to provide reliable and relevant data to further the research objectives and help provide answers to its research questions.

The next sections shall describe the research approach.

3.3 Research Approach

3.3.1 Introduction

It is very useful to understand and clearly specify the research approach used in a research, as the approach influences the research design. It gives the researcher the opportunity to consider how each of the various approaches may contribute to, or limit the study (Creswell, 2013). The extent to which the research is clear at the beginning about the theory raises an important question concerning the design of the research project (Saunders et al, 2016). Understanding and identifying the research approach is useful in that it enables the researcher make more informed decisions about the research design. Furthermore, it helps the researcher think about the strategies and methodological choices that will or will not work. Finally, it enables the researcher to adapt the research designs to cater for constraints (Easterby-Smith et al, 2012). In short, it provides a roadmap on how the research can achieve the set objectives, despite existence of hurdles. Most researchers present two contrasting research approaches: inductive approach and deductive approach. A third: the abductive research approach will be included in this discourse.

3.3.2 Deductive Research Approach

The deductive approach leans a lot towards scientific research and involves the development of a theory that is then subjected to a rigorous test through a series of propositions (Saunders et al, 2016). It develops the hypothesis or hypotheses upon a pre-existing theory and then formulates the research approach to test it (Silverman, 2013). Deductive reasoning derives its conclusions logically from a set of premises, and that conclusion is true if all the premises are true (Ketokivi & Mantere, 2010). The research begins with a theory, an idea, a premise or a hypothesis, and deduces a testable proposition or a set of testable propositions. It then designs a research strategy to test the premises to confirm if the results are consistent with the premises. The theory is corroborated if the results are consistent with the premises (Saunders et al, 2016; Blaikie, 2009; Marcoulides, 1998).

The deductive approach is mostly utilized in contexts where the research is concerned with examining whether the observed phenomena fit with the expectations based upon previous research (Wiles et al, 2011). Since it leans on the methods of the physical sciences, the deductive approach is mostly used within the positivism context (Snieder & Larner, 2009). According to Saunders et al (2016), deductive approach possesses some distinct characteristics. First is the search to explain casual relationships between concepts and variables, using a highly structured methodology to facilitate replication. Secondly, concepts need to be operationalized in a way that enables facts to be measured, often quantitatively. Finally, the sample needs to be carefully selected with an appropriate size and from the appropriate population, to give credibility the generalizations that will be made by the research.

This research does not begin with a hypothesis, neither does it begin with a theory and would therefore not be said to have adopted the deductive approach. It however references the HRO theory as it tries to investigate the extent to which the mindfulness of organisations could be measured; as well as how the measurements, if achievable, could help organisations become more mature. It is going to first observe the behavioural traits and trends of organisations and the social players within those organisations. It will try to identify some patterns in their behaviour and try to generalize based on those patterns. As will be seen in the next section, this is approach belongs to the inductive research approach.

3.3.3 Inductive Research Approach

With increasing studies into the social sciences, researches became increasingly critical of the deductive approach that relied on a cause and effect link between variables, as well as the rigid methodologies without recourse to alternative explanations and the interplay and interactions between social entities. They therefore began leaning towards the inductive approach that was more concerned with the context in which events occur (Saunders et al, 2012). Inductive approach, in contrast with deductive approach, involves a move from the specific to the general (Bryman & Bell, 2015). It does not start with a framework that informs data collection and the research focus is mostly formed after data collection (Flick, 2015), and could then be found to fit an existing theory (Bryman & Bell, 2015).

Inductive approach begins with detailed observations of the world and then moves towards a more abstract generalisation and ideas (Neuman, 2002). It starts with the observations and proposes theories towards the end based on the results of the observations (Goddard & Melville, 2004). It searches for patterns from the observations and the development of the explanations for the patterns through series of hypothesis (Bernard, 2011). Inductive approach does not necessarily preclude theories while developing the research questions; rather it tries to generate meanings from the data set collected in order to identify the patterns and relationships to develop its theory (Saunders, et al, 2016). Lodico et al (2010) considers inductive reasoning a 'bottom-up' approach to knowing, in which the researcher uses observations to build an abstraction, or to describe a picture of the phenomenon that is being studied.

3.3.4 Abductive Research Approach

Abductive research approach neither moves from the data to the theory as seen in inductive approach, nor does it move from theory to the data as seen in deductive approach, but rather seeks to effectively combine both (Suddaby, 2006). The abductive approach moves back and forth between theory and data. It usually begins with an observation, and then works out a plausible reason to explain the observation. As the research progresses, the theories uncover more observations that could lead to the research addressing its assumptions (Saunders et al, 2016; Van Maanen et al, 2007).

Abductive reason is best suited for scenarios where there are incomplete set of observations and therefore proceeds to the most likely explanations for the observations. According to Saunders et al (2016), abductive approach adopts a pragmatist approach to overcome the inherent weaknesses in both the deductive and inductive approaches. Whereas the deductive approach lacks clarity in terms of how to select the theory to be tested through hypotheses formulations, inductive approach is weak in the sense that no amount of empirical data will necessarily enable theory building. This is mostly used in the fields of law, research in artificial intelligence and computing, and research in diagnostic expert systems.

In summary, to best answer the research questions "*to what extent can the reliability of organisations be measured?" and "can the measurements help improve …?"* the research approached the theory development through inductive reasoning's 'bottom-up' approach that uses observations to build an abstraction and describe a picture of the phenomenon that is being studied. The research observed organisations and the social players within the organisations and searched for patterns from the observations. It thereafter developed the explanations for the patterns, and proceeded to make generalizable proposals that would help answer the research questions.

The next section shall discus the methodical choice.

3.4 Methodical Choice

Methodical choice is yet another layer of the ‘research onion’ that must be peeled away to understand the choice of data collection methods. It is one of the three components of research design, the other two being research strategy and time horizon. Research design on its own is the general plan on how the research will progress with answering the research questions (Saunders et al, 2016). Methodical choice centres on the choice of quantitative research design, qualitative research design, or the mixed methods research design, including the various variations of each of them.

3.4.1 Quantitative Research Design

Quantitative research ‘examines relationships between variables, which are measured numerically and analysed using a range of statistical and graphical techniques’ (Saunders et al, 2016). It borrows from the physical sciences, is objective, generalizable, and reliable (Creswell, 2013). Quantitative research puts a lot of consideration on numeric, measurement, sampling, and designing. It also puts a lot of consideration on the analysis of relationships between variables.

It involves statistical and numerical measurement of the raw data captured in questionnaires. It is effective when it involves large numbers of respondents available, where the respondents can be grouped and sub-grouped to achieve the desired objective, where the data can be effectively measured using quantitative techniques, and where statistical methods of analysis can be used . Its results can be used as benchmark with a high level of repeatability (May, 2011).

Quantitative research design therefore is generally associated with positivism, especially when used with pre-determined and highly structured data collection techniques (Saunders et al, 2016). It can however be used to investigate a wide range of social phenomena, including feelings and subjective viewpoints (May, 2011).

Saunders et al (2016) gave further two sub-divisions of the quantitative research design. These include the mono-method quantitative research design and the multi-method quantitative research design. The mono-method quantitative research design uses a single quantitative data collection technique and analyses the technique quantitatively. For instance, this research used questionnaires as a quantitative data collection technique and analysed using corresponding quantitative data analysis tools. The multi-method quantitative research design on the other hand uses more than one quantitative data collection technique in addition to a corresponding quantitative data analysis tool. For example, this research collected data from questionnaires and triangulated this with data from secondary sources such as company financials and company documentations, and analysed these with corresponding quantitative data analysis tools.

Multi-methods are useful due to their likelihood to overcome the weaknesses associated with a mono-method, as well as their ability to provide a more enhanced approach to data collection, analysis, and interpretation (Saunders et al, 2016; Bryman, 2016)

Quantitative research method helped the research identify the objective and observable facts and figures within the organisations devoid of researcher influences. It offered an objective comparison of the reliability of these organisations. It could not capture the subjective realities inferred through the feelings, intuitions, experiences nuances, and individual world views of the social actors involved within these organisations. It could not explain the observable behaviour of the organisations and the social actors within them. The research therefore introduced a qualitative research method to help identify underlying causative factors and mechanisms through which the social structures of these organisations shape the daily actions and interactions of the social players.

3.4.2 Qualitative Research Design

Qualitative research design studies participants' meanings and the relationships between them, using a wide variety of data collection techniques and analytical procedures to develop a conceptual framework and theoretical contribution (Saunders et al, 2016). It is the process of understanding the thought process, the behaviour, experiences, and the perceptions of the social entities in their natural setting, and thus is often associated with interpretivism (Denzin & Lincoln; 2011).

Qualitative research design tries to make sense of the subjective and socially constructed meanings expressed about the phenomenon under research (Saunders et al, 2016) It tries to understand the meaning of the reality under study, as well as the reasons behind the behaviour, thought process, and inter-relationships of the social actors (Creswell, 2013; Eriksson and Kovalainen, 2015).

Qualitative research would usually involve a careful sampling of the respondents, who should as representative of the population as possible, and enables informal interactions between the researcher and the respondents. This informal interaction enables the researcher to build a rapport with the respondent and explore the depths of the respondents' emotions, experiences, and thought process. It would also involve a non-standardized data collection process so that questions and procedure could change and emerge during a research process that is both naturalistic and intelligent (Saunders et al 2016)

Just like in the quantitative research design, Saunders et al (2016) also gave further two sub-divisions of the qualitative research design. These include the mono-method qualitative research design and the multi-method qualitative research design. The mono-method qualitative research design uses a single qualitative data collection technique and analyses the technique qualitatively. For instance, this research collected qualitative data through in-depth interviews, and analysed the results qualitatively using a corresponding qualitative data analysis tool. The multi-method qualitative research design on the other hand uses more than one qualitative data collection technique in addition to a corresponding qualitative data analysis tool. For example, the research might collect data from in-depth interviews and diary accounts and analyse these with a corresponding qualitative data analysis tool. This research used in-depth interviews as the only qualitative data collection technique. It was impossible to adopt the focussed group or the observation method due to the unique nature of this research. First, the researcher could not get authorisation from the management of most of the organisations to form focus groups as it could have been a distraction to the employees. Moreover, the data collection was towards the end of the year, the busiest period for most of the companies. Furthermore, attempting to observe the respondents at work as a method of qualitative data gathering would have been time consuming, and would have involved travelling by boat or helicopter to offshore and swamp locations. This was not realistic due to the huge cost the research would have incurred, the time it would have taken, and the safety considerations given the prevalent challenging security situations within the area. The research therefore arranged interviews to coincide with the time off for respondents in offshore and swamp locations.

3.4.3 Mixed Method Research Design

In addition to quantitative and qualitative research and their variations, a third paradigm, the mixed methods research design is gaining acceptance and use across disciplines (Jalongo & Saracho, 2016; Cresswell & Plano Clark, 2011). It combines the qualitative and quantitative methodologies, and involves the collection and analysis of a combination of both quantitative and qualitative data in a single research (Jalongo & Saracho, 2016; Saunders et al, 2016; Aramo-Immonen, 2013; Cresswell & Plano Clark, 2011; Tashakkori & Teddlie, 2010).

This research involved trying to understand the reliability of organisations and how they behave under certain circumstances. It tried to identify the extent to which the reliability of organisations can be measured, as well as how these measurements can help diverse organisations become more mature.

Quantitative research method would help the research identify the objective and observable reliability facts and figures within these organisations devoid of researcher influences, and offer an objective comparison of the reliability of these organisations. It would however not be able to not capture the subjective realities inferred through the feelings, intuitions, experiences nuances, and individual world views of the social actors involved within these organisations. It would not be able to explain the observable behaviour of the organisations and the social actors within them. Introducing a qualitative research method would therefore help this research to look for the underlying causative factors and mechanisms through which the social structures of these organisations shape the daily actions and interactions of the social players.

By combining these methods in a mixed method design, this research receives two different yet complementary perspectives to the phenomenon. It actively invites us to participate in dialogue about multiple ways of seeing and hearing, multiple ways of making sense of the social world, and multiple standpoints on what is important (Jalongo & Saracho, 2016)

Mixing data however poses the risk of research chaos and confusion due to the use of different terminologies, philosophies, and notation systems and as such, the research design must be clearly articulated (Aramo-Immonen, 2013). When used well, the mixed method has the potential to address the research questions in a more balance manner with better triangulation.

This research therefore uses the mixed method research design only to help provide credible, well founded, reliable, and relevant data that furthers the research objectives and help provide answers to its research questions (Saunders et al, 2016).

The next section shall describe the strategies considered and adopted by this research.

3.5 Research Strategy

For research, just like any endeavour, to be successful, there must be a methodical plan laid out to achieve the set objectives. Steen (2016) defines strategy as "*smallest set of (core) choices to optimally guide the other choices"*. The Oxford dictionary defines strategy as "*a plan of action designed to achieve a long-term or overall aim".* From these definitions, strategy can be said to be at the core of an intended course of action. It ensure consistency throughout a defined period by providing a bird-eye view of all the individual plans and paths and how the fit with one another into the overall strategy. From a research perspective, the research strategy refers to the adoption of courses of actions and the allocation of resources to achieve long term research goals. The strategy for any research should be closely related to the research philosophy adopted by the research (Denzin & Lincoln, 2011).

A research with a positivism philosophy would lean heavily towards a quantitative based research philosophy as positivism deals primarily with discrete observable realities. Quantitative based strategies include experiments and survey (Saunders et al, 2016). On the other hand, a research with an interpretivist philosophy would lean heavily towards a qualitative based research philosophy. This is because the interpretivist tries to understand and explain the reasons behind the actions and interactions of social actors. It would be difficult, for instance, to design an experiment to study how people within organisations react to management of change. Individuals would react in a certain way at one moment and react in a different way at other moments. These actions and reactions could be influenced by the vagaries of human emotions, changes in the social contexts, or biological and environmental changes. A qualitative research strategy would therefore be better suited for researches based on interpretivist philosophy. The strategies to adopt would include narrative inquiry, grounded theory, action research and ethnography.

Finally, a research with a pragmatic philosophy would involve a strategy that combines both quantitative and qualitative strategies. It could mean adopting the archival research or the case study research strategies, or combining two or more of the quantitative and qualitative strategies.

To understand the reasons behind the choice of strategies, it would be important to highlight and understand a few of the strategies considered, as well as the rationale for adopting or rejecting the strategies. This discourse will be arranged in two sub-sections: qualitative data collection strategy, and quantitative data collection strategy.

3.5.1 Quantitative Data Collection Strategy

This research considered three major strategies to help it collect quantitative data. These are experiments, surveys, and archival research strategies. These would be discussed further.

Experiments

Experiment as a research strategy is deeply rooted in the natural sciences. It studies the probability of change in an independent variable causing a change in another variable (Saunders et al, 2016), and typically studies and documents how the identified and manipulated variables affect all the observable outcomes (Fenton & Pfleeger, 1996). It uses null and alternative hypotheses to predict the degree of changes within the variables. Whereas the null hypothesis is the hypothesis that the researcher tries to disprove or nullify, alternate hypothesis is the hypothesis that the researcher is trying to prove to be correct.

Experiment as a strategy was not considered a feasible choice for this research. First the research questions are open – '*to what extent can the reliability of organisations be measured*' and '*how can these measurements…*', and are designed to inquire into the relationships and behaviours of members of certain organisations, as well as how these behaviours differ to other organisations. The research intends to inquire if relationships exist between the variables, and if so, to what extent. Rather than open questions, experiments would use predictive hypotheses (Saunders et al, 2016) to test for expected relationships between the variables. Secondly, the scope of this research would make it almost impossible to design experimental groups and control groups within organisations. Such a project would not be logistically and financially feasible. Finally, it would also be impracticable to design laboratories conditions to perform the experiments.

Given these reasons, the research concluded that experiments would impracticable and not feasible as a research strategy.

Survey

This involves gathering information from an entire group, or more usually samples, which can then be used to make inferences, generate polices, or reveal unsuspected facts. It is usually very effective to answer open questions of *'what'*, *'how much', 'how many' or 'to what extent'*. It allows the researcher to collect a large amount of data from a large population in a cost effective manner, and allows for easy comparison (Saunders et al, 2016). It typically includes the use of questionnaires, structured interviews, and structured observations, all of which are quantitative data collection techniques.

This research considered the use of questionnaires, a survey strategy, as one of the strategies to use as it appeared to tick most of the boxes. First, since the research tends to be exploratory in nature, attempting to explore the behaviours and relationships of organisations and between the members of the organisations, survey strategy would therefore be the obvious and effective choice to answer the research questions '*to what extent can the reliability of organisations be measured*' and '*how can these measurements…*'

Another reason for the choice of questionnaires is the consideration that the use of questionnaires would be a cost effective way of collecting responses from the desired number of respondents. The research needed to study over 500 respondents in eight different organisations across 2 continents. These respondents would comprise of different demographics, be based in different cities, at different work locations, in different organisations, possess different temperaments, and with different availability needs. As such, any other survey strategy would have been a logistical nightmare. In addition to this, the representative nature of the samples reduces the cost, time, and the logistics that would have been incurred should the whole population be surveyed. Thus the survey strategy helps reduce the cost and logistics involved in population sampling, while retaining the accuracy and reliability of the results.

The next reason for adopting the survey strategy was the relative ease the survey instruments would be designed, the ease at which it would be explained, and the ease at which it would be understood. Furthermore, with the survey, it would be easy to run various comparisons between the respondents in the same organisation, between different organisations, and between different demographics.

Finally, this research needed quantitative data to enable it make balanced assumptions. The choice of survey strategy made it possible to collect quantitative data through questionnaires, administered anonymously, and with the responses devoid of researcher influences. These responses would be analysed quantitatively leveraging on one or more of the numerous data analysis instruments available to the researcher.

Archival Research Strategy

This strategy involves a methodical process of identifying relevant archives and extracting relevant original data from them. Archives may include original institutional records, governmental records, media records, or organisational records, archived in libraries or on the internet. This excludes the secondary data and publications related with the subject of research.

To help understand the results from the surveys, this research needed some data. These included organisational reports, safety reports, and financial reports. Some of these were difficult to obtain due to the sensitive nature of the information. Some of the data were however in public domain.

3.5.2 Qualitative Data Collection Strategy

To enhance the quality of the research and to better answer the research questions, this research had to collect qualitative data to better understand and triangulate the results obtained from the quantitative study. The choice of qualitative data collection strategy was influenced by the ability of such a strategy to help understand the thoughts, the behaviour, experiences, the biases, and the perceptions of people within the organisations in their natural setting (Devine, 2002). The research considered the case study strategy, the action research strategy, the grounded theory strategy, and the narrative inquiry strategy. These strategies, as well as the reasons for adopting or rejecting them are discussed further below.

Case Study Research Strategy

The use of case studies as a research strategy has been explained in different ways by different researchers, the variety of definitions stemming from the differing approaches of the various researchers to the development of the methodology (Harrison et al, 2017).

Among the variety of definitions, a common theme in case studies is its definition as a versatile form of qualitative inquiry, most suitable for a comprehensive, holistic, and in-depth investigation of a complex subject in context, where the boundary between the context and issue is unclear and contains many variables (Flyvberg, 2011; Cresswell, 2013; Starman, 2013; Harrison et al, 2017). Yin (2013) further simplifies the definition by viewing it as an in-depth inquiry into a topic or phenomenon within its real life setting. The topic under study could be a phenomenon, an event, a program, a situation, a person, a group, an institution, or an organisation. It typically studies a single subject, but could be designed to show the comparative relationship between subjects.

Despite this variety, Flyvberg (2011) recommends the use of a very basic and simplified definition to avoid the confusion the proliferation of definitions might portend. When designed and executed appropriately, the case study strategy is considered one of the most effective strategies for qualitative (and quantitative) data collection and analysis (Saunders et al, 2016).

Despite the obvious advantages of using the case study research strategy, this research considered it not feasible. First, case study has the disadvantage of relying on small sample size for its effectiveness (Flyvberg, 2011). To effectively answer the research questions, this research expected to study enough respondents to be representative of the population. This meant studying a very diverse sample of over 500 respondents in different organisations and different industries. To achieve this number, this research would have had to design multiple cases for each organisation. Such a venture would have been expensive, a logistics burden, almost not practicable, and beyond the scope and experience of this researcher. Secondly, a case study strategy would involve access into the organisation for long periods, as well as access into certain organisational data bases. Due to sensitivity of operations, such accesses are usually restricted to core employees or consultants with high privacy and non-disclosure agreements. The research therefore considered it impracticable to request for such access.

Finally, Yin (2013) and Flyvberg (2011) admit that the sample size in case studies may be too small to make the results generalizable. This research aims to create a model that would be used to access diverse organisations. To achieve this, the sample size must be representative enough so the results could become generalizable. Given these disadvantages, this research considered case studies inappropriate for use as the sole source of data. Some case studies were however considered to help understand the results from this research as well to help deepen some phenomenon discussed in the research such as disasters.

Action Research

Saunders et al (2016), citing Coghlan (2011) and Coghlan & Brannick, 2014) defined action report as an ‘emergent and iterative process of inquiry that is designed to develop solutions to real organisational problems through participative and collaborative approach, which uses different forms of knowledge, and which will have implications for participants and organisations beyond the research project’. It begins with a question or a problem, and works through series of iterations to reach a result or set of results. In an organisation based research as this, the action researcher would normally act as the facilitator and work with members of the organisation to arrive at a potential resolution.

For this research, adopting the action research strategy would involve the participation by the members of the organisation and their collaboration with the researcher to study the organisations' work practices. Such participation and collaboration would have been difficult to achieve for the same reasons as explained in case studies: the size of the sample, the logistical nightmare, the cost, the difficulty of access, and the sensitivity of some operations. Furthermore, this strategy would meet with obvious resistance from a large spectrum of the employees, some of whom may consider this an unnecessary distraction from their day to day activity (Reason, 2006), especially that safety is a considered as a 'non-event'; something that have not happened and hence difficult to justify.

In addition, for an action research to be effective, the organisation (or members of the organisation) would need to identify a gap or gaps within their organisational process, the resolution of which would impact the organisation positively. This means that the need for the change has to come from within the organisation to enable the members buy into the participatory and collaborative approach that underpins action the research. The research questions for this research do not indicate such need and could therefore meet resistance from within the organisation. The research therefore considered action research not appropriate to meet the research needs.

Glasser and Straus' Grounded Theory

Grounded theory is a research strategy that involves forming a theory based on the gathered data as opposed to gathering data after forming a theory. The theory is grounded on the data, looks at a particular situation and tries to understand what is going on (Kervin et al, 2006). It is based on interpretivism and is designed to understand the meanings that social actors ascribe to their experiences, observations, and interactions in specific situations (Saunders, 2016; Suddaby, 2006).

To triangulate the results obtained from the quantitative aspects of the study, obtain a balanced view, and to better understand the meanings that underpin the actions and interactions of members of the organisations under study, this research adopted the interview strategy. This qualitative approach involved obtaining data from the interviewee, interpreting the data, and using the data to refine further questions and iterations. This is a key element of the grounded theory strategy. As the interviews progress, relationships and patterns between the responses begin to form. These relationships and patterns would be fed back into the research and compared with results obtained from the quantitative approach for triangulation.

Effective use of grounded theory is dependent on the amount of time and expertise available to the researcher. It is cumbersome, requires a lot of time and effort, and has the potential to accumulate unimportant information. Additionally, wrong use of the grounded theory may lead to ethical issues. There is the potential for the use of leading questions and the information could therefore be tainted by biases from both the interviewer and interviewee. All these were considered and would be discussed further under the ethics section.

Narrative Inquiry

Narrative inquiry was the last qualitative strategy considered and is fairly related to grounded theory, the difference being in the nature of data obtained from the interviews. It invites the respondent to provide a complete narrative of their experiences and viewpoints (Chase, 2011). This narrative is the main intent of subjective data for this research, as it enables the researcher to understand the in-depth views, experiences, value systems, and biases of the respondents.

Additionally, using the narrative inquiry strategy meant that the research obtained contextual details of the organisations' deeper realities closely linked with their social relationships (Gabriel & Griffiths, 2004). To enhance the quality of the responses, the in-depth interviews were conducted across a broad spectrum of the organisations being studied. It allowed this research to analyse the linkages, relationships, and the explanations across the spectrum, thereby allowing it to understand the complex processes the respondents used in making sense of their organisational realities. Finally, this research considered the narrative inquiry a simpler strategy to adopt that the grounded theory.

To summarise, this research considered different research strategies and chose a combination of the survey method and in-depth interviews. First, this combination helps the research to obtain a combination of objective and subjective data. It is also the best combination to answer the exploratory questions '*to what extent can the reliability …*' and '*how can these measurements…*' Furthermore, survey was considered to be cost effective and less logistically demanding than the others, and with the ability to reach the intended respondents within the time frame. Finally, both strategies were considered easy to design and administer. The next section shall discus the time horizon involved in this research.

3.6 Time Horizon

Time horizon is the final layer of the 'onion' that must be peeled away to reveal and understand the choice of data collection and analysis methods. It is the timeframe within which the research is expected to be carried out and completed.

Some research may not be time dependent or times constrained, and are designed to study the relationships between variables over extended periods of time. These are longitudinal studies (Saunders et al, 2016). The researcher is able to track data and changes in the data over an extended period. Cross-sectional studies on the other hand are time dependent and the data is obtained within a defined time snapshot. The research question would normally give an indication of the type of time horizon to be used.

This is useful as it makes the researcher aware of the impact of time on the quality of the research. For certain time dependent researches, a change in certain social realities could affect the objectives of the research and render the research useless.

This research requires data to be collected within the snapshot. A respondent could change responses should the social realities that influenced the choice of those responses change. For instance, a respondent's feeling about the organisation could change following a catastrophic event within the organisation or with the industry. The responses could also change should the respondent suddenly receive bonuses due to an improved company financials. This research therefore falls within the cross-sectional study time horizon. Nevertheless, the research method is clearly set and justified in such a way so that other researchers in different times can replicate the proposed framework and model.

The next section shall describe the data collection process as well as the considerations made during the data collection process.

3.7 Methods for Data Collection

This section outlines the considerations made by this research during the data collection process. It describes the sample population and the considerations made during the sampling process. It describes the questionnaire design and the assumptions made during the design. It concludes with the assumptions, considerations and lessons learned from questionnaire administration and collection process.

3.7.1 Sampling Technique

The two major sampling techniques considered were the probability and non-probability sampling techniques. Probability sampling refers to any technique where the chance of being selected is known and is the same for all members of the sample population (Saunders et al, 2016). With this, it is easy to make statistical inferences about the characteristics of the population and reach generalizable conclusions from the research. For non-probability sampling on the other hand, the chances of being selected from the sample population is not known, neither is it possible to make statistical inferences about the characteristics about the members of the sample population.

For probability sampling to work, the sampling frame must be available. This is the complete list of all members of the target population. For this research, this would mean a complete list of all organisations. It would also mean a complete list of all employees within those organisations. Since the sample frame comprises the entire target population, the probability sample would be representative of the entire target population, the selection would eliminate bias, and the results could be used to generalize the characteristics of the entire target population.

While it might be possible to get a list of registered organisations, knowing with certainty that the list would be accurate might not be feasible. In addition, the process involved in compiling such a list would involve a lot of time and huge resources, both of which the research does not have the luxury of. Getting the complete list of all members of the organisations would therefore be beyond the scope of this research. Furthermore, this research is not designed to make generalizations about organisations.

It is designed to study individual organisations and how they differ from one another in terms of organisational reliability, with a view to developing a model that could utilize those differences to help other organisations tend towards more mindfulness, reliability, and maturity. This research therefore concluded against the suitability of probability sampling to further its research objectives and provide answers to its research questions, and therefore settled for non-probability sampling techniques.

Various techniques are available for use as part of the non-random technique, the choice of which must be selected carefully with the research questions and objectives in mind. This research utilized the quota sampling and purposive sampling techniques throughout the sampling process. The quota sampling technique is a stratified non-probability sampling technique based on the premise that the sample within strata will represent the target population since the variability in the sample for the various quota variables is the same as that of the target population (Saunders et al, 2016). Its likelihood of being representative is reasonably high, but will depend of the selection of the quota variables

Pilot Study

The pilot study was purely a non-probability purposive sampling, where the researcher selected known associates that would be expected to give honest opinions about the survey design and the issues being studied. Purposive sampling technique (Saunders et al, 2016) involves the use of judgement to select the cases that will be most beneficial to meet the research objectives and answer the research questions. It sacrifices the statistical representation of probability sampling on the altar of information-rich benefits. The research weighed the need for statistical representation and the need for obtain as much information as possible to enable it set the direction of the rest of the research and decided that the benefits of the information far outweighed the need for statistical representation and therefore settled for the purposive sampling technique.

The pilot study was conducted within the production and maintenance department of a multinational petroleum company in Nigeria. 20 respondents were selected in a purely a non-probability purposive sampling. The sample was demographically stratified in terms of current responsibility, years of experience, and gender. Considering current responsibility, 10% of the respondents were people in management positions, 30% were respondents in supervisory positions, and 60% were respondents at the shop floor based on conventional wisdom of the staff – supervisor – manager ratios. This is expected to be representative of the ratios within most organisations.

Considering years of experience, the research developed a five level stratification for years of experience in the industry, ranging from below three years; between three to seven years; above seven years and below 15 years; 15 to 25 years; and above 25 years. This five level stratification assumes that new employees in an industry would spend the first three years trying to adapt and understand the peculiarities of industry.

Assuming the employee joined at the shop floor level, the experience and motivation level would be expected peak within three to seven years of work. At this point, the employee would expect to be transitioning into a supervisory role. After 15 years in the industry, the employee would have become highly experienced and would be expected to be transitioning into a management role, or already in that role.

Over the career lifecycle, the employee experiences and motivation levels would be expected to change, so will their perceptions and attitudes. For instance, a new employee or a newly promoted employee would be expected to have a higher motivation level than an employee that has spent over 10 years in the industry and is still stuck at the shop floor, especially if the employee believes he/she has more to offer. The employees would have different world views about their jobs, and their perceptions about the nature of reality would be different.

Similarly, an employee that has spent over 10 years on a role would have a different perception about the nature of reality from an employee that has just completed an orientation for the same role. Their perceptions about safety and risk taking would be expected to differ. The routine of lubricant replacement could become monotonous to the staff with 15 years' experience on the job to the point of complacency, causing the staff to bypass procedures, often with catastrophic consequences.

After 25 years, most employees would be past their mid-career, at which point, opinions and perceptions would also be different. This stratification therefore helps the research to obtain data from people at different career levels and with diverse perspectives on the social realities within the organisation, with a view to providing depth and balance to the results.

Finally the pilot gave consideration to gender stratification, with the perception that gender might also influence the respondents' world view and their belief of what constitutes the nature of reality. The research expects that the diversity that this type of stratification brings would help expand the responses, and enhance the research validity and reliability.

Benefits of the pilot to the main study

The main objective of a pilot test is to pre-test the research instrument and provide information that could potentially enhance the research's reliability and validity (Van Teijlingen & Hundley, 2001). The pilot for this research was therefore designed to test the feasibility of the research, the suitability of the survey instruments, identify and address potential logistical issues that may arise during the main research, and assess the outcome in terms of the research objectives. In addition, it was also intended to test the researcher's preparedness and ability to conduct the main research. Should the pilot test fail, the research would assume that the premise of this study is faulty, thereby potentially saving the time, money and effort that would have been otherwise invested in the research. Finally the results of the pilot test would help this research to refine its research questions for better chances of success (Saunders et al., 2016).

The pilot achieved most of these. By successfully completing the pilot with a 100 percent return rate, this research became confident that the instrument was simple, easy to understand, and in that regard, therefore suitable for this research. The pilot also helped to confirm the ability to reach the required respondents in terms of their stratification and helped focus the main research on the need to work with the gate keepers on the need for an effective stratification of the respondents. Furthermore, by reviewing the results from the pilot, the research was able to test the usability of the results to develop the measurement framework required to answer the research questions. Had this failed, then the premise on which the research was built would have been considered faulty and reviewed or the research abandoned. This therefore gave clarity that the research was on the right track. Finally, the pilot helped the researcher develop confidence in his ability to complete the survey.

The Main Study

The main study followed the same assumptions made during the pilot study in terms of purposive sampling and respondents' demographic stratification. In addition to these, the research had to make a decision about the choice of organisations to study. In adopting the technique for the choice of organisations, the research considered the organisations where rich and contrasting information would be obtained, instead of just considering statistical representation – a purposive sampling technique. The research purposively contrasted the choice of organisations in terms of size, age, and geographical spread, so as to add depth and diversity to the final data. For each large organisation, a relatively smaller one was chosen; for each new organisation, a relatively much older organisation was selected; and for each localized organisation, an organisation with a relatively wider geographic spread was selected. If organisation A is an old organisation with national spread and expansive networks, organisation B would be a direct contrast: relatively new and relatively smaller. This is expected to provide different and deeper information sets that will help answer the research questions.

The interviews were also based on the same stratification as the questionnaires, but on a much smaller scale. The research adopted a loose ratio of 10 questionnaires to 2 interviews spread among the 3 strata of management, supervisors, and the shop floor.

3.7.2 Research Population and Participation

The research population refers to the entire subject matter of interest a under investigation by the research (Sekaran & Bougie, 2016). It includes entire people, groups, events, organisations, occurrences, or things under investigation. It may not always be possible to research the entire population, and as such a sample is selected from the population. The validity of the research and its results will be called to question if the sample is not representative of the entire population.

One of the main objectives of this research is to study organisations outside the traditional high reliability organisations, with a view to investigating the extent of their operational and cultural similarities and differences, as well as understand how these differences may influence the organisations' mindfulness. To achieve this, the sample size must be representative of the organisations. Nigeria was chosen for primary research due to the researcher's location and experience, as well as the possibility of obtaining the required side of data.

The main research was conducted in eight organisations in three industries across two continents, again using purposive sampling technique to determine organisations where rich and contrasting information would be obtained. The three industries were selected to contrast with existing research on the HRO theory, which had been concentrated on certain industries. Furthermore, these three industries have potentials for incidents of catastrophic proportions. The reasons for the choices, the nature of catastrophic events, as well as a few examples of past catastrophic events within these industries is highlighted below.

Oil and Gas Industry

The oil and gas industry was selected due in part to the researcher's experience in the industry, as well as the ability to call upon previous contacts to gain access for data collection. The researcher's experience in the industry is expected to create a spirit of camaraderie among the respondents, the effect of which is expected to be honest and sincere responses. Secondly, the oil and gas industry in has experienced some major accident hazards in the past and is expected to be a mine for the type of data required to effectively carry out this research. Finally, the research expects that given the catastrophic nature of possible effects of lack of mindfulness within the oil and gas industry, the industry should have evolved to design processes and practices to guide its practices and operations.

A 2016 report by the bureau of labour statistics at the United States department of labour (Bls.gov, 2017) considers the oil & gas industry to be one of the most hazardous industries with an average annual fatality count of 109 between 2003 and 2015. According to the report, this represents an average of 14 fatalities for every 100,000 employees.

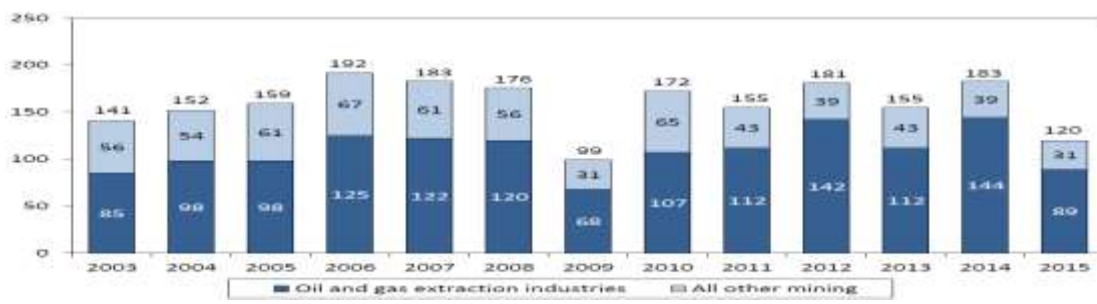


Figure 3.2: A graph showing oil and gas fatalities (oil & gas figures in deep blue) blueA Oil & Gas fatality report 2003–2015. Source: (Bls.gov, 2015)

In addition to fatalities, catastrophic events from oil and gas operations could result in environmental pollution, explosions, and fire. An oil tanker, the Amoco Cardiz, sank on the 16th of March 1978, spilling about 1.64million barrels of crude near the northwest coast of France. Millions of molluscs, sea urchins, and other sea creatures were killed, and France presented a legal claim of US$2 billion to the United States courts (Visser, 2010). A liquid petroleum gas explosion in November 19th 1984 in San Juanico, Mexico destroyed the plant, killing 600 people and severely burnt about 7000 people in the neighbouring San Juan Ixhuatapec (Arturson, 1987). The Piper Alpha oil production platform disaster of July 6, 1988 (Ross, 2008) in the North Sea killed 167 people with a total insured loss of about US$3.4 billion. An explosion at the Texas City refinery on the 23rd of March 2005 killed 15 people and injured over 180 others (US CSB, 2005). The Deepwater Horizon oil disaster of April 20, 2010 in the Gulf of Mexico, killed 11 people destroyed the platform, and spilled about 4.9 million barrels of crude into the sea with huge impact on marine life (National Response Team, 2011).

Beverage & Brewery Industry

The research also identified the beverage manufacturing industry as a potential industry where small lapse in mindfulness could lead to catastrophic loss of lives. For instance, Nigerian Breweries Plc, controls over 60% market share in the Nigerian Breweries industry (Proshare, 2017). With the hot and humid weather, majority of Nigerians use Nigerian Breweries products daily with their meals, for entertainment, and for recreations. This means that with a population of about 186 million (CIA, 2017), over 112 million people could potentially be directly affected by an error in the manufacturing, or distribution process. A simple calibration error in the manufacturing process could lead to food poisoning of catastrophic proportion, the fallout of which most organisations may not survive.

The London beer flood of October 17th 1814 spilled 1.47 million litres of beer into the streets. The wave destroyed homes and killed 8 people, including 2 toddlers (Greenberg, 2006). The Boston Molasses flood of January 15, 1919 caused by a burst tank, resulted in a wave of molasses rushing through the streets at an estimated 56 km/h, killing 21 people and injuring over 150 others (Puelo, 2004). Should this happen in a major city today during peak hours, the resultant catastrophic effect would increase exponentially. More recently in Honolulu, Hawaii, 1400 tons of molasses were spilled into the harbour in September 2013 as a result of a faulty pipe. Most aquatic life around the vicinity was reported killed.

Restaurant Chains

Finally, the research identified the restaurant chain as another industry where a minor lapse in mindfulness could lead to catastrophic loss of life. This choice is to include a service related organisation to contrast with the manufacturing and production related organisations already identified.

Food contamination could also be a major source of disaster for a restaurant chain and history is rife with such incidents with multiple fatalities. The contamination could happen at any point in the supply chain. There have been instances where chicken feed were contaminated, leading to poisonous chicken and eggs being used in multiple service locations. There have also been similar cases with milk, meat, and grains. 732 people were infected with E.coli in 1993 when Jack in the Box, a US restaurant chain, served infected burger across 73 locations in the United States. 4 children died, and 178 people were left with permanent damage.

In addition to Jack in the Box, E.coli outbreak have affected other major restaurant chains including Kentucky Fried Chicken (KFC), McDonald's, Sizzler, Wendy's, and Taco Bell all with catastrophic consequences. Burger King, another restaurant chain, was forced to recall 25 million pounds of beef from 650 locations in 1997 after E. coli contamination got 16 customers sick. In 2003, 640 people were affected and 4 died in Pennsylvania, USA, when tainted tomatoes at Chi-Chi's restaurant caused a hepatitis A outbreak. The reputation of the organisation never recovered. The reputation of Chipotle, another restaurant chain, took a major hit in 2015, when sick employees led to an outbreak that affected almost 400 customers.

The final consideration made during the choice of organisations was the need to accommodate organisations of various sizes to eliminate the potential bias. For instance, larger and more established organisations within an industry is expected to have a more evolved procedures based on their past experiences. Multinational companies would also be expected to leverage on their global corporate strategies organise the processes different from their smaller local counterparts. Smaller organisations may just be concerned with meeting their financial obligations and insist of production at the expense of safety. On the other hand, some smaller organisations may be interested in the sustainability of their small businesses and design a highly reliable process, whereas laxity and over confidence bias may be introduced into larger and older organisations.

This research therefore mixed up the organisations with larger and smaller organisations, multinational and local organisations, and older and newer organisations to generate a wide range of data that could potentially help address the research questions.

Summary of Organisations

These organisations chosen will be referred to as Company A, B, C, D, E, F, G, and H at this stage. The eight organisation, A, is a multinational oil and gas company based in Canada, and responses were obtained from their locations in Canada. This was chosen to triangulate the results that would be obtained from the organisations in Nigeria. The summary is presented in the table below.

Table 3.1: A Summary of research participation showing the companies, the number of respondents, and the number of interviewees for each company

RESEARCH PARTICIPATION				
Organisation	**Location**	**Consideration**	**Questionnaires**	**Interviews**
Oil and Gas				
A	CANADA	Multinational organization. Expected enhanced processes and culture. To be used for triangulation	40	6
B	NIGERIA	Multinational organization. Expected enhanced processes and culture. Large employee base	50	10
C	NIGERIA	Local organization. Smaller than B, but Larger than D. Newer than B, but older than D.	30	5
D	NIGERIA	Local organization. New. Small employee base	30	5
Beverage Manufacturing				
E	NIGERIA	Large operational base. National spread. Decades of operation.	50	10
F	NIGERIA	Regional operational base. New organization	50	10
Restaurant Chain				
G	NIGERIA	Regional operational base. New organization	50	10
H	NIGERIA	Large operations base. National spread. Decades of operation.	70	15

Determining the Sample Size

Determining the appropriate sample size for a given population is a critical process that must be undertaken carefully. While a small sample size relative to the population increases the margin of error (De Vaus, 2014), a very large sample size relative to the sample population will be an expensive and logistical nightmare to achieve. For this reason the sample size must be carefully determined with considerations to the total population being studied, the confidence level, and the confidence interval.

The confidence level is the amount of uncertainty the research can tolerate (Saunders et al, 2016). It is the percentage of all possible samples that can be expected to include the true population parameter, and is directly proportional to the sample size. It states the precision of the estimates of the target population as a percentage that is within a certain range of margin of error (Saunders et al, 2016). For this research, a 95% confidence level is assumed. At 95% confidence level, 95 out of 100 samples are expected to be representative of the true characteristics of the true population. This implies that the true population parameter would be included in 95% of the confidence intervals. Extrapolating 95% confidence level from a Z table the Z score would be 1.96. 1.96 would therefore be used in this research as the confidence level.

Confidence interval on the other hand is the amount of error the research can allow. It is usually referred to as the margin of error and is expected to be as low as reasonably practicable. It determines how much higher or lower the population mean the research is willing to let its sample mean fall. The larger the sample size, the lower the margin of error. This research assigned a margin of error of +/-5%

Standard deviation is a measure of the level of variance expected from the responses. A generous standard deviation of 0.5 ensures a sizable number samples with the allowed margin of error.

The research assumes a population of 5.26 million based on the Nation Master Labour statistics' (Nationmaster, 2017) estimates of the labour force employed in Nigerian industries.

Given these variables, a number of options are available to calculate the sample size. These include the formula method, use of standard calculators and the graphical method. The formula and the software are described below.

Formula

A number of formulas are available ranging from simple to the very complex. Smith (2013) gives a very simple formula for calculating sample size and is shown below.

$$N = Z^2 * P\,(1 - P) / E^2 \tag{3.1}$$

N = minimum number of samples

Z = confidence level (1.96 – see in section 3.7.2.3)

P = standard deviation (0.5 – see section 3.7.2.3)

E = confidence interval (+/-5% - see section 3.7.2.3)

$$N = 1.96^2 * 0.5(1 - 0.5) / 0.05^2$$

This gives the value of the required sample size to be 384.

Software

A quick search on the internet will show numerous software and websites that will automatically generate the sample size when the variables are inputted. The variables for most of them include the confidence level, the standard deviation, and the confidence interval. For all the software tested, the research obtained the same value of 384 as the sample size.

3.7.3 Questionnaire Design

A questionnaire is a data collection technique in which respondents are requested to respond to the same set of questions in a pre-determined order (Saunders et al, 2016). It includes questions and statements designed to seek appropriate information and allow for easy analysis. It is a very effective and generally accepted method of quantitative data collection from large samples (Saunders et al, 2016; Bell & Waters, 2014; Dillman et al, 2014; Teddlie and Tashakkori, 2006). To ensure effectiveness, the individual questions must be carefully designed; the visual presentation must be clear and pleasing; and the purpose must be lucidly explained. It should also be pilot tested and the administration executed to perfection (Saunders et al, 2016)

The questionnaire used in this research is based on the work of Weick & Sutcliffe (2007) that seeks to explore how organisations could maintain a resilient performance in an age of uncertainty, as well as how organisations could learn high reliability organisations. Information based on the experiences of the researcher, information from different professionals, and organisational improvement texts from different organisations have been used to enrich the questionnaire. Weick & Sutcliffe (2007) had identified five principles of high reliability organisations to include preoccupation with failure, reluctance to simplify, sensitivity to operations, commitment to resilience, and deference to expertise. They designed a set of question for each of these principles to help organisations spot the five principles in their processes.

Weick & Sutcliffe used a combination of a three points rating system and a two points rating system to design their questions. In some of the principles, the respondents are requested to select between numbers one, two, and three, to describe how each of the statements describes their work units, departments, or organisation. The selections one, two, and three in this instant stand for: not at all; to some extent; and a great deal respectively. In some other principles, the respondents are given only two choices: agree and disagree, and are requested to indicate whether they agree or disagree with the provided statements.

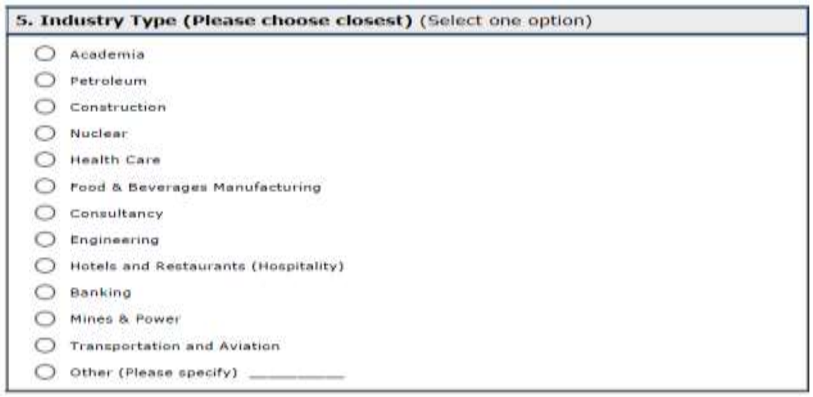
This research considered that a five points rating system would expand the options available to the respondents and enhance the chances of getting deeper, richer, and wider range of responses. Furthermore, harmonizing into a single five point rating system would make it easier for the respondents to follow through, instead of jumping between two different rating systems in the same questionnaire. The available responses are one, two, three, four, and five for strongly disagree, partially disagree, neither agree nor disagree, partially agree, and strongly agree. This is to help maintain uniformity throughout the research and avoid confusing the respondents (Dilmal et al, 2014). The neutral point of neither agree nor disagree also helps the respondents sit on the fence when considering an implicitly negative statement or potentially uncomfortable statement. This also helps collect more expansive responses from the respondents on a wide range of issues rather than just a two point scale of 'agree or disagree'.

The other difference between this questionnaire and that by Weick & Sutcliffe (2007) lies in the choice of questions. The questions have been expanded in this research to include more areas not covered by Weick & Sutcliffe (2007). For instance, considering preoccupation with failure, this research expanded the questions to fifteen from the original ten. The questions are made to follow the sequence that would be expected in an actual incident from near miss or incident reporting, to documentation; through the root cause analysis, recommendation implementation, and the finally the lessons learned. Furthermore, the questions are made more active by making the respondent feel a part of the organisation and a part of the research. This is achieved by the consistent use of the pronouns "we" and "our" throughout the questionnaire. The respondent is therefore made to feel he/she is talking about himself/herself, instead of "them". The next section describes the questionnaire design in more details.

The design

The questionnaire starts with a cover letter that introduces the research and the researcher. It provides informed consent and assures on confidentiality. The second page provides a brief description of high reliability organisation and the five principles of high reliability organisations to help the respondents deepen their understanding of the concept being studied and its relationship with their individual organisations.

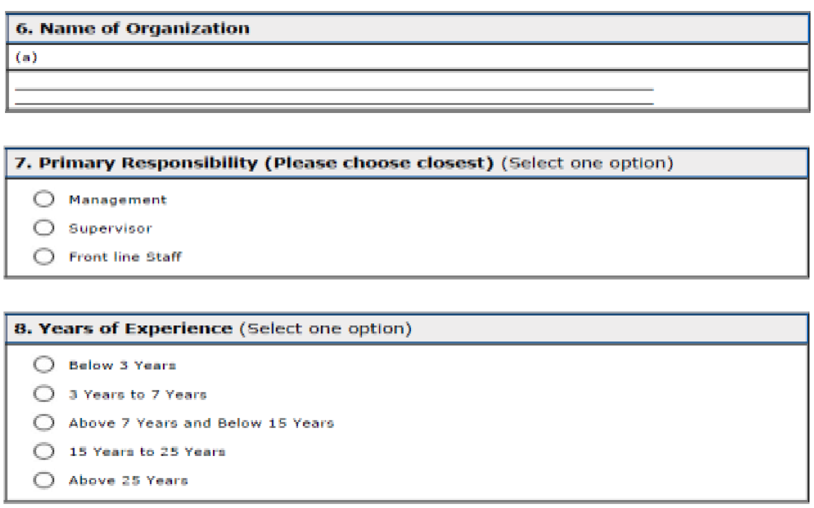
The next page collects demographic information with a dropdown selection to indicate demographic information. All the demographic questions are provided in a list question format. Information includes industry type:


5. Industry Type (Please choose closest) (Select one option)

- ○ Academia
- ○ Petroleum
- ○ Construction
- ○ Nuclear
- ○ Health Care
- ○ Food & Beverages Manufacturing
- ○ Consultancy
- ○ Engineering
- ○ Hotels and Restaurants (Hospitality)
- ○ Banking
- ○ Mines & Power
- ○ Transportation and Aviation
- ○ Other (Please specify) ________

Fig 3.3: Excerpt from the questionnaire showing demographic question on industry type

The next page identifies the name of organisation (or its code name), primary responsibility of the respondent, and years of experience of the respondent within the industry.


6. Name of Organization

(a)

7. Primary Responsibility (Please choose closest) (Select one option)

- ○ Management
- ○ Supervisor
- ○ Front line Staff

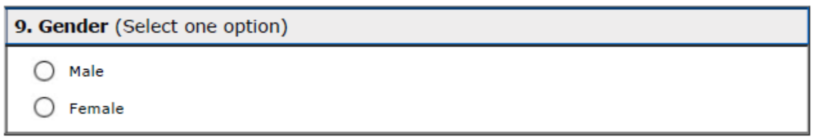
8. Years of Experience (Select one option)

- ○ Below 3 Years
- ○ 3 Years to 7 Years
- ○ Above 7 Years and Below 15 Years
- ○ 15 Years to 25 Years
- ○ Above 25 Years

Fig 3.4: Excerpt from the questionnaire showing demographic question on responsibility and experience

Years of experience in the industry was chosen over years of experience within the organisation because of the attrition rate within some industries. A management employee could be less than three years within an organisation but has spent over 25 years in multiple roles in other organisations. Provided the roles were within the same industry, the risks and experiences are considered similar and transferable, and therefore should count for this research.

Finally the research requested gender information to gauge if the trend could show the role of gender in certain responses.


9. Gender (Select one option)

- Male
- Female

Fig 3.5: Excerpt from the questionnaire showing the demographic question on gender

The actual research questions were split into five sections, with each section representing one high reliability organisation principle.

Section 1: Assessing preoccupation with failure

There are 15 questions within this section. The questions are arranged in a five point rating scale of strongly agree, partially agree, neither agree nor disagree, partially disagree, and strongly disagree. Weick & Sutcliffe (2007) rightly designed their questions to gauge the respondents' impressions about their organisations preoccupation with failure. They however failed to mention incidents and near miss reporting, how they are documented, and what the organisations do with the documented reports. Observing, reporting and documenting near misses and incidents are key steps to eliminate or reduce the incubation period in Turner's man-made disaster model (Turner, 1978). In most of the disaster cases described in chapter two, the incidents could have been avoided or the effects reduced had there been a good culture of reporting, documentation, and action close out. The lookouts in Titanic noticed some haze within the horizon ahead of them but failed to report (Barratt, 2010). This research considers incident and near miss management as a key aspect of an organisation's preoccupation with failure and has therefore added questions to reflect this. The research also unbundled the incidents and the near misses and treated them as clearly separate entities. An organisation that is not mindful might neglect near misses to its peril. Frank Bird analysed the general results of more than 1,000,000 incidents and concluded that a relationship exists between the number of near misses and an eventual injury or equipment damage (Morrish, 2017). He considered near misses as incidents with no visible damage or injury and used his research to design an incident triangle that describes the relationship between near misses and incidents (figure 3.6)

Figure 3.6 Bird's incident triangle (Bird, 1992)

From the triangle, for every 600 near misses, there are 30 equipment damages, 10 minor injuries, and 1 major injury. Borg (2002) argued against this, stating the blurry line between minor and major injuries. He simplified the triangle and grouped the injuries together to include 1 injury and 3 equipment damage from 30 near misses (this should actually be 60 near misses from simple mathematics)

Figure 3.7 Borg's incident triangle (Borg, 2002)

If the near misses are considered as warnings, this triangle suggests that there must have been 10 warnings before equipment damage would occur, and 30 warnings before an injury. With this idea of a near miss as an asset damage, or injury, or fatality waiting to happen, this research justified its inclusion of incident reporting, as well as unbundling the near misses and incidents in its questionnaire.

The questions are arranged to flow through the failure analysis process: observing the incident/near miss; reporting it; a database of the reports being maintained; root cause analysis being performed; actions being assigned to investigate and prevent reoccurrence; applications of leaning from failures; regular reviews, perception of the people that file the reports; perceptions of the people who are involved in the incidents; near misses; and unsafe acts or unsafe conditions. The questionnaire is attached in appendix 3.

Each question ends with an open question type with provision '*other (please specify)*'. This is to enable the respondents indicate their own thoughts on the question. Finally, each section ends with a rand order type question set, in which the respondent is asked to rank the questions in order of importance to them, with 1 being the most important, and the last number on the list being the least important among all the selections.

Section 2

Sections 2 follows the same pattern as section 1 and makes the same assumptions in terms of the type of the rating questions style, the rating scale used, the open question for '*other*' to enable the respondents' opinions, and the ranking type questions at the end to enable the respondents rank the questions in order of importance. The section assesses how organisations balance simplification and standardization of processes with actively seeking to avoid undue generalisations on how and why things work or fail.

The research recognises that the culture in some organisations is built such that career advancement becomes a function of the extent to which the individual conforms to whatever processes and behaviours exist within the organisation. People would not want to be labelled as "process disruptors" and therefore scepticism is silenced. The unintended consequence is that people would make potentially damaging observations about the processes but would choose to look the other way. For a manufacturing organisation, dripping oil from an engine could be an indication of a seal failure or internal failure with potentially catastrophic consequences on the whole process. For fear of punishment, or what people might say or do, or what they might not say or not do, the observer might just clean the drip and walk away. Overtime, the drips might be seen as a norm and overlooked, possibly with disastrous consequences.

This section therefore sets out 12 questions to gauge the organisations' reluctance to simplify. The questions include the ability of people to challenge the procedures and processes, as well as how the organisation treats critics and sceptics. It also gauges the level of shared trust among people within the organisation, how viewpoints are respected or not. Finally it gauges how much people are encouraged to deepen their understanding and analysis of processes and the nature of problems to be better prepared to challenge them or solve the problems when they arise. The NASA Challenger disaster could have been prevented had the management not oversimplified the flaw in the O-Rings designs when their engineers reported the issue. They did not respect the engineers view points and failed to challenge the process with their senior management. Similar to this, the management at NASA oversimplified and considered as acceptable risk the possibility of foam insulation shedding off from the external tank of Columbia's shuttle, leading up to the Columbia disaster. The events leading up to the Texas City incident described in chapter two had occurred several times in the past, but the events were oversimplified, and learnings were not applied. The questionnaire is therefore designed with consideration to the issues around oversimplification.

Section 3

Section 3 assesses the organisations' sensitivity to operations: their responsiveness to details of their operations; their staffing adequacy; competence and motivation levels; and their ability to detect and competently react to slight changes in the process. The section consists of 11 questions built around each individual being mindful of assigned jobs, having an overview of other jobs going on around, how the jobs relate with one another, as well as being able to participate in jobs outside own areas of competence. It also assesses the communications among staff, between staff and management, relationships among staff, and between staff and management. It assesses the leadership and decision making process, as well as availability of resources to manage unexpected issues. Most of the disasters discussed in chapter two had sensitivity to operation at the heart of their causative factors. For instance, from chapter two, the crew of Columbia appeared to have been rushed into the launch, with very limited time to prepare, and they did not have adequate basic personal protective equipment. Investigations into Piper Alpha incident revealed that the disaster resulted from inadequate communication among staff, inadequate communication between staff and management, insufficient duty of care, poor operational decision making by those responsible, breakdown of the chain of command, and inadequate maintenance and safety practices. There were also issues around sensitivity to operations in the BP Texas city incident, and the Deep Water Horizon incident. These issues bothered around deviation from procedures, inadequate supervision, unclear chain of command, ambiguity in roles and responsibilities, inadequate communication, inadequate hazard identification, inadequate trainings, and delays in reacting to signals. The eleven questions have been carefully selected to cover these issues around sensitivity to operations.

Section 4

This section assesses the organisations' commitment to resilience: the ability of the organisation to respond to incidents, recover from failure, learn from it, and restore operations to the conditions before the incident. It assesses the organisations' emphasis on technical, behavioural and attitudinal competence; the extent to which these competencies are assessed; and the availability of relevant skillsets for all aspects of the processes. It also assesses the emergency response and contingency plans; how they are deployed; and how the people accept and implement the processes.

Finally it assesses the availability of formal and informal contacts the people can access to solve problems and how aware people are aware of the availability or otherwise of these key contacts. These questions would also attempt to close the gaps around commitment to resilience described in the seven cases in chapter two. In the case of

Columbia, it was discovered that there were no emergency response processes built into the system to enable effective rescue missions and on-orbit repairs by the shuttle astronauts should the need arise. Furthermore, the emergency response practices leading up to the Texas City incident was considered inadequate by the post disaster investigations. The same was identified in the Deepwater Horizon incident, where the final events were considered at best chaotic: people were unsure whether to muster, wait for lifeboats, or jump into the sea. The emergency response equipment such as lifeboats was considered grossly inadequate to handle the emergency. The questions in this section are designed to investigate the level of preparedness of organisations for emergencies.

Section 5

This final section assesses the extent to which the leaders in the organisations are willing to set aside hierarchy and respond to the insights from experienced and competent staff for each particular emergency, despite their position within the organisation.

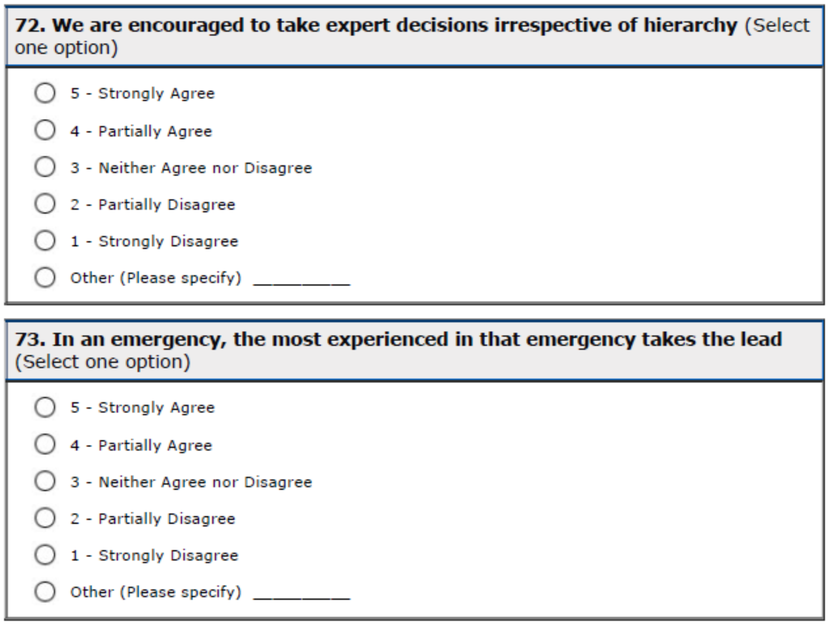
The section has eight questions that try to assess peoples' respect for one another's job. It tries to assess if for instance, the general manager will yield authority to the security person during a security emergency despite the security person's hierarchical position within the organisation. It also assesses if electrician at the shop floor is valued and respected as much as the process analyst or the human resource personnel at the head office, all of whom are key elements of the organisations' success or failure. It assesses how much people are committed to doing their jobs well; the availability of different key expertise for all anticipated emergencies in all key areas of the organisations' processes; and the extent to which people know who has the most expertise for different aspects of the organisations' processes. The section also assesses how much expertise and experience are valued over rank during emergencies. Finally it assesses how responsible people feel about problems until they are resolved.

The Piper Alpha incident is a clear example of the dangers of not deferring to expertise during emergencies. The staff at Tartan and Claymore were experienced enough to know they should shut down their facilities to reduce the effect of the incident, but waited for shutdown instructions from their hierarchical leadership. This delay fuelled the disaster and massively escalated it.

As already stated, the questionnaire is influenced by Weick & Sutcliffe's questionnaire, the researcher's industry experience, experiences of the research supervisors, and knowledge sharing sessions with industry and subject matter experts. For instance, some of the questions were heavily influenced by the researcher's health, safety and environment (HSE) background. In addition to the experiences of the research supervisors, subject matter experts, the questions were also influenced by past experiences where people potentially fail to report issues for fear of a punitive measures and low end of year appraisal. Furthermore, the reluctance to simplify section for instance was heavily influenced by the researcher's involvement in several "war room" sessions, where people from diverse backgrounds, viewpoints and temperaments are brought together to "think outside the box" on performance and organisational improvement initiatives and processes.

The incident described in section 2.5.9, after the discussions on deference to expertise, played heavily on the choice of some of the questions, especially in the sections 'sensitivity to operations' and 'deference to expertise'. If an employee hits the emergency shutdown button due to a potential incident leading to production loss, how will the employee be treated within the organisation? What if it turned out to be a false alarm and the process was not really in danger? How would such employee be treated in the organisation? Are the employees expected to seek management approval to shut down the operations during an emergency?

Questions such as the ones below were designed to find out how the organisations would react when faced with a scenario as above



72. We are encouraged to take expert decisions irrespective of hierarchy (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ________

73. In an emergency, the most experienced in that emergency takes the lead (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ________

Fig 3.8: Excerpt from questionnaire showing sample questions

Finally, some questions were found to fit into more than one section. In such instances, the individual judgment of the researcher was used to determine the section that best fits the question. The two questions below found in section 3: assessing sensitivity to operations are perfect examples.

"*Everyone is expected to take decision, such as operations shutdown to forestall catastrophic failure"*

"*People have discretion to resolve unexpected frontline problems without differing to leadership"*

These questions could easily fall under section 5: deferring to expertise. The research however considered that operational shut down during emergencies should not just be left to experts, but should be an operational decision, the decision of which should rest on everyone. The same explanation goes with people having the discretion to resolve unexpected frontline problem. Although this also is closely related to difference to expertise, it also borders on sensitivity to operations. When people are sensitive to operations, they will quickly resolve frontline issues before it escalates.

Interviews

In addition to the questionnaires, semi-structured interviews were designed to delve deeper and obtain qualitative details about the issues raised in the questionnaires. It helps to obtain the story behind respondents' knowledge (Cohen & Manion, 1994), and to attain in-depth knowledge about the phenomenon under investigation (Wahyuni, 2012). The questions were loosely based on the questionnaire, but the respondents were asked to give their opinion about the questions.

The selection of interviewees was done in a stratified manner to ensure the distribution of the interviewees in line with employee supervisor manager ratio as previously discussed. The research adopted a ratio of 10 questionnaires to 2 interviews spread among the 3 strata of management, supervisors, and the shop floor. Letters were sent out to the managers and supervisors through the gatekeepers with a date agreed between gatekeepers and the researcher for the interviews. The eventual interviews were based on availability of the managers and supervisors. Interviews for people on the shop floor on the other hand was carried out purely based on availability on the proposed date as some of the proposed interviewees were on shift related work cycles. This was facilitated through the gatekeepers.

The interview started as a semi-structured interview with similar questions but with the flexibility to use closed-ended and open-ended questions. It then gradually developed into an unstructured interview format that would rely on the social interaction between the researcher and the respondent. This helped to expose the researchers to unexpected ideas that potentially helped illuminate the respondents' social reality.

The interviews were structured into six sections. Section one was designed to capture the interviewees' demographic information. It contained questions to extract the respondents' gender, industry, organisation, primary responsibility, and years of experience in the industry.

The next five sections discussed each of the five HRO principles, much similar to the questionnaires. Each of these five sections had general open ended questions, as well as questions that tried to personalize the interviewees' experiences. Section two captured the interviewees' experience with respect to assessing preoccupation with failure. Questions include investigations on how the organisations manage near misses and incidents, with follow up questions around reporting, incident database management, and overall perspectives about near misses and incidents. Questions also include what processes are available to prevent recurrences of incidents and near misses, and to prevent these from escalating. Follow up questions include processes around incidents and near misses analysis, learning from incident, and use of worst case scenarios during planning and analyses. The section also asked questions to gauge the focus of organisations on successes or failures, how the organisations treat people that make mistakes, and the nature of communications between the staff and management, and among the staff. The section ends by asking about the personal experiences of the interviewees with respect to failure.

Section three assessed the reluctant to simply in organisations. The interviewees are asked their opinion about skeptics and people that challenge the norms, as well as how they are perceived within the organisation. The section asks to know the behaviour of organisations towards learning with a follow up to know if learning is geared towards understanding processes. There are also questions around the interviewees' impression about the level of trust that exists within the organisation, as well as the extent to which everyone's viewpoints are heard and taken into consideration. Finally the interviewee is asked if he/she has ever taken something for granted that turned out to lead to failure, and if it has previously happened within the organisation. The interviewee is asked to describe the incident and the effect it had on the organisation as well as the lessons learned.

Section four assessed the sensitivity to operations. It asks about the nature of team meetings and tries to understand the frequencies, usefulness, participation, and terms of reference of team meetings. It also asks the level to which superiors and managers intervene in daily activities, and how this is perceived by the employees. It asks about the feedback process and field supervision, the extent to which supervision is available in the field, and the extent to which field leadership can take decisions without deferring to management. In addition to these, the section asks the question: "*If someone interrupts the process to forestall a catastrophic failure, what would happen? What if it turns out to be a false alarm?"* The section ends by exploring the interviewees experience about the nature of communication available between frontline and management, and among staff.

Section five assesses commitment to resilience. It asks the question "*What emergency response and contingency processes are available?*", "*how do people respond to these processes?*" It asks questions that explore the availability of required skillsets within the organisation and how the skills are assessed. Finally it asks about the interviewees' personal experiences about emergencies, details of those emergencies, how they were managed, the effects of those emergencies, and the lessons learned from how those emergencies were managed.

The final section assesses deference to expertise. It asks personalized questions around the leadership structure during emergencies, as well as the relationship between the experienced people and the management staff during emergencies. It tries to understand the difference, if any, in the leadership of teams during emergencies and under normal operations. Finally, the section tries to understand the level of expertise available within the teams.

In summary, the interviews are structured such the "*reasons behind the responses*" from the questionnaires are identified. The questions delve deeper into the responses from the questionnaires to understand the perceptions and experiences of the respondents and therefore throw light into the responses. Finally, the interviews would be useful to triangulate the results obtained from the questionnaires. The next section describes the data administration and collection process. A copy of the interview questions is attached on appendix 4.

3.7.4 Administration and Collection

This section will briefly describe how the questionnaires were administered as well as the challenges encountered. The research initially chose the online as its preferred method of questionnaire administration. This was to ensure wider distribution and enhance anonymity. Sogosurvey was selected from the pool of other electronic survey instruments available. It was easy to set up given the researcher's lack of experience with online survey instruments. The technical team of sogosurvey was also easily available through the online chat service, through telephones, and through emails to offer assistance when obvious hitches were encountered. Finally it was offered free as a student package and its cost effectiveness was a relief to the research.

All the 20 pilot questionnaires were returned successfully and the results documented. The 20 test questionnaires included 2 questionnaires administered to people within the management cadre, 8 were administered to people within the supervisory cadre, and the rest administered to people at the shop floor. This was the expected percentage representation for the rest of the research.

However, after 4 months of administering this survey through the gatekeepers, and repeated reminders, the response rate was still at 3.8% with 668 questionnaires delivered. The strategy was changed to distribute paper questionnaires using the same gatekeepers, but with the researcher making personal visits to these organisations. With this strategy, the desired sample size was obtained.

3.8 Reliability and Validity

Reliability and validity are key concepts that determine the quality of a research (Saunders et al, 2016; Golafshani, 2003).

3.8.1 Reliability

Reliability refers to the ability of the research to be replicated with consistent results. An unreliable research will prove to be invalid since any error or bias will affect the results and subsequent interpretations, casting doubts on the means to measure the phenomenon being studied (Saunders et al, 2016). Biases and errors from both the participant and researcher could affect the reliability of a research, and care must be taken to ensure these biases and errors are eliminated or reduced to as low as reasonably practicable.

For this research's questionnaire, reliability was achieved by the robustness, simplicity, and clarity of the wordings so that the meanings would remain the same with different respondents. Within the same organisation, the responses within certain groups were mostly similar, and consistent, indicating a high reliability. For instance, the managers appeared to answer in the same line, the supervisors appeared to be fairly consistent across the questions, and the employees at the shop floor appeared to be fairly consistent with their responses.

Finally, throughout the questionnaires there are deliberate alternative forms (Mitchell, 1996) introduced at random. These are check questions or group of check questions deliberately introduced with different semantics. The responses for these check questions are expected to be the same, thereby confirming reliability. For instance the question: *'we have well defined emergency plans'* and *'we have well defined contingency plans'* are similar and should have similar responses. A well-defined emergency plan must contain contingency plans. Similarly, the questions: *'people in the organisation value expertise over rank'* and *'we are expected to take expert decisions irrespective of position or rank'* are similar questions worded differently, but are expected to generate similar responses.

Table 3.2 and Table 3.3 demonstrate the reliability of the research in terms of check questions. Both tables show the comparison of the results obtained in the check questions and indicate how close the responses are.

Table 3.2 – Comparison of the results from the emergency/contingency check questions

	Availability of defined emergency plan	**Availability of defined contingency plan**
Company A	100% at level 5	100% at level 5
Company B	100% at levels 4 & 5	100% at levels 4 & 5
Company C	100% at levels 4 & 5	100% at levels 4 & 5
Company D	100% at levels 4 & 5	100% at levels 4 & 5
Company E	32% (5), 30% (4), 26% (3), 12% (2), 0% (1)	32% (5), 30% (4), 26% (3), 12% (2), 0% (1)
Company F	100% at levels 1-3, 78% of which are at levels 1-2.	100% at levels 1-3, 88% of which are at levels 1-2.
Company G	100% at levels 1 - 3	100% at levels 1 - 3
Company H	0% (5), 0% (4), 8% (3), 38% (2), 54% (1)	0% (5), 0% (4), 8% (3), 38% (2), 54% (1)

For the questions *'we have well defined emergency plans'* and *'we have well defined contingency plans',* the responses are very similar in almost all the organisations. In Companies A, B, C, and D, all the respondents chose responses between levels 4 and 5 in both sets of questions. The responses in both sets of questions match exactly in companies E and H. In a similar set of questions '*we are aware of the emergency response plans'* and *'we are aware of the contingency plan',* similar the research obtained similar results as above. The responses were exact matches in companies E and H with very close responses in the other organisations.

For the questions, *'people in the organisation value expertise over rank'* and *'we are expected to take expert decisions irrespective of position or rank',* the research obtained similar results (Table 3.3).

Table 3.3 – Comparison of the results from the expertise over rank check questions

	Value expertise over rank	**Expert decisions irrespective of position or rank**
Company A	100% at level 5	100% at level 5
Company B	100% at level 1 & 2	90% at level 1 & 2
Company C	0% (5), 0% (4), 6.67% (3), 36.6% (2), 56.6% (1)	0% (5), 0% (4), 6.67% (3), 36.6% (2), 56.6% (1)
Company D	100% at level 1 & 2	87% at level 1 & 2
Company E	100% at level 1 & 2	82% at level 1 & 2
Company F	100% at level 1 & 2	92% at level 1 & 2
Company G	100% at level 1 & 2	97% at level 1 & 2
Company H	100% at level 1 & 2	96% at level 1 & 2

Reliability is difficult to achieve in qualitative research such as in the case of the interview technique adopted in this research (Saunders et al, 2016), largely due to the fact that repeatability is not feasible in a subjective process. The interviews are designed to be flexible, with open ended questions designed to engage the respondent and gain insights about the feelings, experiences, and social reality of the respondent. Recreating the exact circumstances, mood, emotional conditions and environments that produced the social interaction is not feasible, therefore reliability is not considered in that respect for the interviews. However, it must be pointed out that the reasons underpinning the choice of interview technique as already highlighted was to understand more of the reasons behind the responses in the questionnaire, thereby triangulating the findings.

3.8.2 Validity

Reliability alone is not enough to enough to justify the quality of a research. A research could be reliable but not valid; it could also be valid not reliable. A research must therefore be both valid and reliable to be considered of good quality. Validity refers to the appropriateness of the measures used, the accuracy of the analysis of the results, and the generalizability of the findings (Saunders et al, 2016).

For this research, validity is verified by first through content validity. Content validity is an internal validity that refers to the extent to which the questions provides adequate coverage of the research objectives and research questions. According to Littlejohn et al (2017) described two ways in which content validity could be established. These are through expert interviews and pilot study. Various literatures on high reliability organisations have been reviewed and all the principles extracted. The questionnaire was developed to cover all principles of high reliability organisation theory. Opinions from seasoned industry experts, the academia, members of the supervisory board for this research and examiners from the major review and subsequent annual reviews were collated and used to update the questionnaire and thus enhance the content validity.

The research considered validity during pilot testing by ensuring a similar spread as would be expected from the actual research. Out of the 20 respondents, 2 were in management positions, 8 in supervisor positions, and the rest in the shop floor. This is similar to the distribution one would expect from the sample population. The responses from pilot testing were compared against each other within similar strata. The research expected the responses from respondents within similar strata in similar industries to be similar. These results are expected to be different from responses obtained from different strata. For instance, the responses from managers were expected to be slightly different from the responses from people on the shop floor. This research achieved this as expected in all the HRO principles, and in all the organisations surveyed. The evidence and details of this can be found in section 4.4. The results from the pilot test, and the ability of the research to use the same content utilized in the pilot test to successfully complete the research further affirms the validity.

Validity is also a function of the ability of the research to do what it set out to do, answer its research questions using appropriate methodologies, and develop generalizable findings that are easily replicable. The research started out to explore the extent to which the reliability of organisations could be measured, as well as the ability of such a measurement framework to be and utilized to improve diverse organisations. These were clearly defined at the beginning of the research and everything in the research was building up to solve these. The ability of this research to develop the maturity model ORM^2 (discussed further in section 5), and the measurement framework FORM (discussed further in section 5) are further testaments to the validity. The research was replicated in eight different organisations, from three different industries and in two different continents with very similar results. This replicability further adds to the research validity.

Issues around construct validity as it relates to this research would be discussed in the limitations section.

3.9 Ethical Considerations

This research was conducted in full consideration of the University of Portsmouth ethics policy of November 2013. There was no primary data collection until the research had been ethically reviewed by the University Ethics Committee and approval received to commence.

Clarity

The language was clear and concise, devoid of unnecessary ambiguity. The objectives were clearly spelt out both on the questionnaires, on the request letters and on the consent form. There was a clear and brief description of HROs, and this was added as a footnote to the ethical review documentation to aid their decision. The principles of HRO were also briefly and clearly described to the respondents so they are clear on what the expectations are.

At the beginning, the research had intended to conduct a forensic on some organisations that had collapsed and try to investigate how high reliability organisation behaviour could have prevented their demise. In the course of the ethical review, there was the realization that having been defunct for years and the employees moved on or retired, the memories of some of the proposed respondents may have become blurred or somewhat biased. This could potentially lead to their responses not being accurate representations of the events and actions that may have been obtainable or prevalent at the time the organisations were operational. This group was therefore excluded to remove this bias.

Gaining Access

Gatekeepers were used to distribute the questionnaires and to gain access for the interviews. Gatekeepers were used to ease the distribution burden, as well as eliminate the bias of the researcher selecting only respondents that could further the research assumptions. The use of gatekeepers presented its own ethical consideration: gatekeeper bias. The gate keepers could potentially select respondents based on personal or organisational interests, with negative impacts on the quality of the research.

To eliminate this bias, the research held initial discussions with the gatekeepers in an attempt to obtain an employee list, at the least coded with numbers to maintain privacy. It would have been easy to send out the questionnaires from numbers selected at random from this sample frame. This was not feasible due to the extra effort that would have been required from the gatekeepers to code the list with numbers, as well as the effort to transcribe the codes into emails for the distribution list. The compromise was to indicate a percentage of distribution, whereby the managers received 10-20% of the questionnaires, supervisors received 20-40% of the questionnaires, and the rest of the employees received 40-60% of the questionnaires. Finally the use of semi structured interviews that enabled follow up questions helped triangulate the results from the questionnaires, thereby limiting the gatekeeper bias.

Consent and Anonymity

Cover letters and consent forms were sent in advance of the interviews so the interviewee is aware in advance of all the requirements without pressure or prejudice and to ensure the ethics committee requirement for informed consent is met. Furthermore, each questionnaire begins with the cover letter, which specifies informed consent.

For the interviews, in addition to the consent form, the interview will start with explanation of the research objectives, as well as expected format and questions. A verbal informed consent was obtained from each interviewee before commencing the interview.

For anonymity, the respondents were not required to sign the consent form, but were made aware that continuing with the questionnaire would indicate consent.

Furthermore on anonymity, there are no names on the questionnaires and all publications will be anonymised. Electronic survey instrument (sogosurvey) was used to enhance anonymity. Where hard copy questionnaire are used, names were not mentioned. The research realizes that it is technically possible to obtain names and details of respondents in online survey instruments, but have no intention of doing this.

Some of the organisations requested not to be mentioned in the report for confidentiality purposes. Due to this, codes will be used to represent the organisations at this point.

Data Safety

All responses obtained through emails will be downloaded from the online survey instrument and stored on an encrypted and locked hard drive with backup stored on the locked N Drive and google drive. All data will first be grouped and coded, while the code identifiers will be stored separately. Data from paper questionnaires were also extracted, coded and stored on an encrypted and locked hard drive with back up stored in the N Drive and google drive. As in the case of the online questionnaires, the codes and code identifiers are stored separately .The paper copies are locked away in a home safe.

Data analysis will be through statistical means using university resources. At the end of the research, all raw data will remain in the research repository for use in further post studies papers for about five years. Thereafter they will be discarded. However, the analysed data will remain the researcher's secure repository for future referencing. The google drive is tied to the researcher's student email, which is locked and secured.

Risks

There were no potential risks to the respondents.

The major risk to the researcher was security challenges prevalent in most parts of Nigeria. The north east was embroiled with the Boko Haram armed conflicts; the south had the Niger delta militancy challenges, and the Biafra agitations for secession, and a non-Muslim conduction research in the far north would easily stand out and could potentially become a target for some criminal elements. Finally, recent political activities and harsh economic conditions have led to increased crime rate: robberies, kidnapping for ransoms, ritual killings, and fraud. The researcher therefore had to devise means to navigate through these harsh realities safely.

These were initially intended to be avoided through the use of online survey instrument. However, due to low response rate from the online instrument, the researcher had to resort to traveling between sites, and residing in the area for 2 months for the data collection. The researcher however, limited movements within major cities and remote locations where safety was relatively assured. In cases where the respondents in remote locations that were considered relatively unsafe were required, the researcher relied on the gatekeepers to deliver the questionnaires.

3.10 Chapter Summary

This chapter has presented the considerations and assumptions made by the researcher in the course of the challenging and interesting data collection process. The research adopted the research onion (Saunders et al 2016) as a theoretical lens through which the process was navigated and explained. The research combined this theoretical lens with many other sources to describe the philosophies, approaches, and strategies adopted, and well as the reasons for adopting them and discarding others. Furthermore, the chapter described the data collection process, highlighted the successes and challenges encountered during the process. Finally, it described the reasons why the results of the research should be trusted, its limitations, and all the ethical considerations made.

The revised research onion below summarizes the methods and methodology adopted in this research to arrive at the data collection and data analysis.

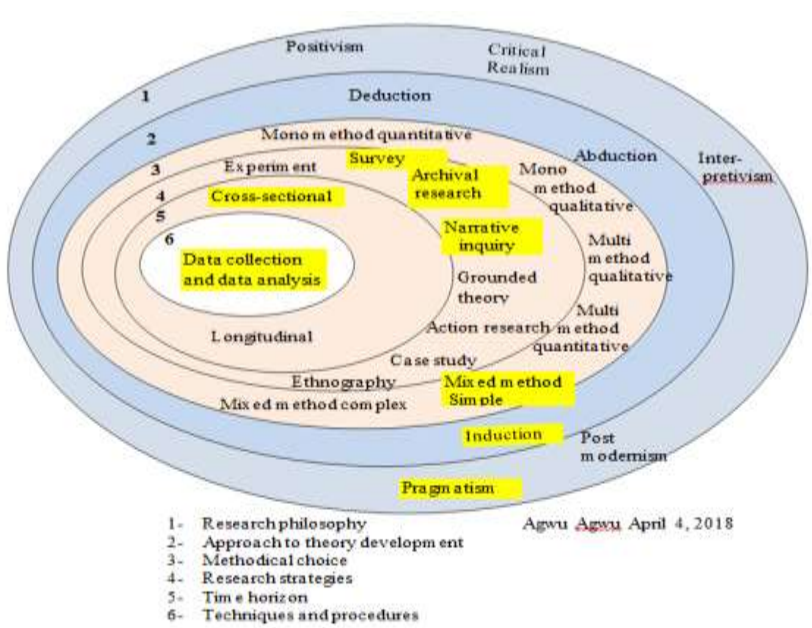


Fig 3.9: Revised research onion showing the choices made by this research highlighted in yellow

Chapter four shall describe and analyse the results. The chapter will describe all demographic data including results based on gender, years of industry experience, and primary responsibilities. It will describe results based on all the five HRO principles and the results based on all the organisations studied. These results will set the stage for assessing, comparing, benchmarking, and improving the organisations as shall be discussed in the subsequent chapter.

CHAPTER FOUR

Results and Analysis

4.1 Introduction

Chapter three described the methods for data collection utilised in this research and presented the methodologies adopted to justify the method choices. The chapter described in details all philosophical considerations and assumptions made by the research, the research approaches, the methodical choices, and the research strategies adopted. Finally, the chapter described all ethical considerations made in the course of data collection, including considerations around language clarity, gaining access, gatekeepers, informed consent, anonymity, data safety, and risks.

Chapter four will present the findings from the data collection process. It will present the demographic profiles of the respondents in terms of gender, level of experience, and primary responsibility. Furthermore, chapter four will also present the findings based on each of the five principles of high reliability organisations. Finally, chapter four will discuss the results based on the different organisations studied. It will try to analyse these results and their implications to this research.

4.2 Response Rate

The questionnaire response rate differed with the nature of the distribution. The pilot study recorded a 100% response rate. This could have been as a result of a combination of reasons. First, the sample size was relatively small and the researcher was able to reach each of the respondents personally either on phone or via email to solicit their support.

Secondly, the researcher purposively selected a sample that would potentially embody the intent of the research. The questions were relevant to the industry selected, and most of the respondents were familiar and could relate with the concept being studied.

Thirdly, the questionnaire was designed to enable easy response. Walonick (2004) argues in favour of the benefits of a well-designed questionnaire to a high response rate. The research therefore put in a lot of effort to ensure a relevant and high quality questionnaire. There was a cover letter that clearly explained the subject under study, explained the response selection process, and guaranteed anonymity. Furthermore, the questions followed a logical sequence and appeared to tell a story, making it easy for respondents to flow with.

The main research initially conducted through an online survey instrument – sogosurvey.com, recorded a very low response rate at less than 4%.

Since the same questionnaire was used as in the pilot study, one would have expected similar response rate. The following are possible reasons for the low response rate.

The researcher relocated out of the geographic location earmarked for the research at the same time the questionnaires were about to be delivered. This made communication with the gate keepers, and the respondents limited.

The researcher also discovered in the course of the interviews that although internet connectivity is widespread within the geographic location, its use by a majority of the people is mostly limited to online news and social media outlets. 60% of the questionnaires delivered were not read, 4% read and answered, while 36% were read but not answered. Some respondents interviewed said they received the mail on their cell phones, and could not therefore have downloaded and satisfactorily completed the questionnaire. This could account for why some were read but not answered. Most respondents agreed that they do not check their emails regularly, except their work emails, and when they do, it would normally be on their cell phones. Some confessed to having multiple private emails, but could not remember the last time they opened the inbox to check emails. Almost everyone accepted that they check their social media every day. It is therefore likely that the online questionnaires delivered through emails may have been lost in the myriad of emails and spams in the respondents' inbox. The researcher therefore learned that perhaps, subsequent online questionnaires could be delivered through social media instead of emails.

Finally, although all the respondents confirmed the availability of internet access and data connectivity, most of them complained about the cost and strength of the data connectivity. The networks may be readily available, but the signal strength may not be enough to enable them download the questionnaire, nor sustain the connectivity long enough to complete the questionnaire. Furthermore, the cost of the data connectivity for personal use in most cases might become a hindrance and deter potential respondents from completing the questionnaires.

Due to this low response rate, the research adopted paper questionnaires and distributed them through gate keepers. This received a much higher response rate as shown below.

Table 4.1 – A summary of questionnaire responses showing returned and validated

QUESTIONNAIRE RESPONSE SUMMARY				
ORGANISATIONS	ISSUED	RETURNED	INVALID	VALID
A	40	40	0	40
B	50	50	0	50
C	30	30	0	30
D	30	30	0	30
E	60	52	2	50
F	60	51	1	50
G	50	50	0	50
H	80	72	2	70
	400	375	5	370
		93.75		92.5

Out of the 400 questionnaires issued, a total of 375 were returned, giving a response rate of about 94%. This is an impressive response rate given that Williams (2003) considers questionnaire response rates to fall between the ranges of 10% to 90%. Out of the 375 returned questionnaires, five were voided due to incomplete responses. 92.5% of the questionnaires were validated and used for the analysis.

4.3 Demographic Data

As described in chapter three, the organisations would be referred to as companies A, B, C, D, E, F, G, and H. A summary of the organisations is shown below to aid the demographic discussions to follow.

Table 4.2 – Summary of the organisations researched

RESEARCH PARTICIPATION				
Organisation	**Location**	**Consideration**	**Questionnaires**	**Interviews**
		Oil and Gas		
A	CANADA	Multinational organization. Expected enhanced processes and culture. To be used for triangulation	40	6
B	NIGERIA	Multinational organization. Expected enhanced processes and culture. Large employee base	50	10
C	NIGERIA	Local organization. Smaller than B, but Larger than D. Newer than B, but older than D.	30	5
D	NIGERIA	Local organization. New. Small employee base	30	5
		Beverage Manufacturing		
E	NIGERIA	Large operational base. National spread. Decades of operation.	50	10
F	NIGERIA	Regional operational base. New organization	50	10
		Restaurant Chain		
G	NIGERIA	Regional operational base. New organization	50	10
H	NIGERIA	Large operations base. National spread. Decades of operation.	70	15

4.3.1. Gender

The oil and gas, as well as the beverage manufacturing industry, appear to be dominated by the male gender based on the summary of the gender demographic represented in this research. This dominance is very obvious in organisations B, C, and D where the cumulative male - female gender spread is a ratio of 70:30. Organisation A, and D have gender ratios that are similar at 57.5:42.5 and 60:40 respectively.

Table 4.3 – Demographic Spread based on Gender

GENDER										
	A	B	C	D	E	F	G	H	Total	Average
Male	57.50%	65.00%	83.33%	60.00%	66.00%	78.00%	28.57%	24.00%	462.40%	58%
Female	42.50%	35.00%	16.67%	40.00%	34.00%	22.00%	71.43%	76.00%	337.60%	42%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	800.00%	100%

A closer look at these organisations could explain this trend. Organisations A, B, C, and D, are oil and gas exploration and production organisations and are therefore expected to engage more engineers or engineering related personnel. Mann & DiPrete (2013) showed that although the female gender has surpassed the male in college completion, there has been a slow integration of female in the pursuit of science, technology, engineering and mathematics. According to their research, the female gender received 40% of bachelor's degree in science, technology, engineering, and mathematics related fields as of 2000, up from about 25% in 1997.

This is similar to the National Household Survey (Hango, 2017) research published in 2017 Statistics Canada, that found women to account for 39% of university graduates with degrees in a science, technology, engineering or mathematics related field. This gap is even wider in engineering. According to the National Household Survey and Statistics Canada (Hango, 2017), only 23% of the engineering graduates were women. The survey summarised that women were much less likely at 23% to choose a career that involves science, technology, engineering, and mathematics than their male counterparts, regardless of their ability.

With these in perspective, it is could be understood why the gender ratio among respondents in this research in the oil and gas sector is tilted towards the male gender. Another reason for this gender spread may be connected with the location and nature of the jobs. Respondent in organisations C, and to a large extent organisation B were based in offshore and swamp locations, where the organisations' operations are concentrated in. The personnel in these locations are resident in camp style accommodations on a two week work rotation cycle. These locations are far removed from civilization, would mostly involve long distance helicopter flights and boat rides, and are known to have security challenges. These conditions might further deter some people from working in these environments: most married female, and married female with young children interviewed would rather not work in these environments if they have the choice. Organisations A and D have their locations based mostly on land locations, closer to major cities, and with most employees working off their main offices mostly located at the city centres. This potentially attracts a more diverse workforce as evidenced in a closer gender ratio than organisations B and C.

Organisations E and F are beverage manufacturing companies and follow similar trends as the oil and gas organisations in terms of the relationship between the engineering discipline and gender. Furthermore, a lot of the manufacturing activities involve lots of manual lifting and packing, long hours of standing on different production lines, and therefore appear to be male dominated. Based on information gathered from the interviews, the culture within the respondents' locality appears to see such manual jobs as responsibilities for the male. This also conforms to Statistics Canada (2017) survey that gives the ratio of male to female in the manufacturing industry as 72:28.

The restaurant chains recorded a reversal in the gender ratio. Organisation G and H had 28.57% and 24% males and 71.43% and 76% females respectively. This high female to male ratio could be tied to the service oriented nature of restaurant chains, as well as the location of the restaurants themselves. Statistics Canada (2017) showed that 55% of employees within the service industry are females. The same statistics shows that within the food services industry, almost 60% of the employees are female. Given the gender inequality in the primary research location, Nigeria as described by British Council (2012) and the World Bank (2017), and the percentage of female employed within the food services industry as described by Statistics Canada, the gender ratio exhibited by organisations G and H could be said to be accurate representations of the industry.

4.3.2. Responsibilities

This research assumed a narrow definition of span of control (Schyns et al, 2010; Gumusluoglu &et al, 2013) as the number of direct reports a particular supervisor or manager has at any given time. Some researchers (Hattrup, 1993; Davison, 2003; Gupta, 2010) had considered span of control as the number of direct reports that can be managed effectively and efficiently by supervisors and managers in an organisation. They had also considered the advantages and disadvantages of adopting a narrow span of control or a wide span of control. They identified factors that could influence an organisation's choice of optimal span of control to include size of the organisation, nature of the organisation, and nature of the job. Other factors include skill and competencies of the managers or supervisors, skills and competencies of the employees, and the type of interactions that exists between the supervisors or managers and the employees. Given that different organisations with diverse organisational structures, cultures, and general organisational behaviour would be studied, this research adopted a span of control that is neither too wide nor too narrow. The research therefore structured the survey such that about 10% of the respondents would people in management positions, 30% would be respondents in supervisory positions, and 60% would be respondents at the shop floor.

The result indicates that on average, 48% of all respondents were people on the shop floor, 37% of the respondents were supervisors, while the remaining 15% were people in management positions.

Table 4.4 – Demographic Spread based on Responsibilities

RESPONSIBILITIES										
	A	B	C	D	E	F	G	H	Total	Average
Shop Floor	57.50%	40.00%	56.67%	50.00%	46.00%	40.00%	50.00%	42.86%	383.02%	48%
Supervisors	30.00%	40.00%	33.33%	33.33%	40.00%	40.00%	40.00%	42.86%	299.52%	37%
Managers	12.50%	20.00%	10.00%	16.67%	14.00%	20.00%	10.00%	14.29%	117.45%	15%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%		100%

This result was fairly the same in most of the organisations studied. The slight exceptions were organisations B, F, and H where the ratio of the people on the shop floor and the supervisors was evenly split. This could be because most supervisors in these organisations grew from the shop floor and would assume shop floor responsibilities when required. All the organisations maintained an average of about one manager to six reports, or more accurately, three managers to seventeen reports.

4.3.3. Years of Experience

The result shows an average even split among all the stratified experience groups. 18.62% of all the respondents are employees with less than three years of experience in their respective industries; 27.01% have between three to fifteen years industry experience; and 22.50% have stayed within the industry longer than seven years but less than fifteen years. Furthermore, 20.12% of the respondents have between fifteen to twenty five years industry experience; while the remaining 11.75% have spent over twenty five years within their respective industries. The lower percentage of people with over twenty five years' experience is expected due to the possibility of retirements, pursuit of different career choices, and other age related issues.

Table 4.5 – Demographic Spread based on Years of Experience

YEARS OF EXPERIENCE										
	A	B	C	D	E	F	G	H	Total	Average
> 25	17.50%	12.50%	16.67%	23.33%	20.00%	4.00%	0.00%	0.00%	94.00%	11.75%
15 - 25	30.00%	27.50%	43.33%	26.67%	18.00%	8.00%	6.00%	1.43%	160.93%	20.12%
>7<15	17.50%	35.00%	20.00%	26.67%	32.00%	28.00%	18.00%	2.86%	180.03%	22.50%
3 - 7 Yrs	17.50%	15.00%	16.67%	16.67%	18.00%	38.00%	40.00%	54.29%	216.12%	27.01%
< 3	17.50%	10.00%	3.33%	6.67%	12.00%	22.00%	36.00%	41.43%	148.93%	18.62%
										100.00%

Looking more closely at the organisations, the oil and gas organisations had more percentage of respondents within the seven to twenty five years' experience brackets than other industries. The research period coincided with the period of oil price drop and employee layoffs. Organisations would normally rely on their experienced people to guide them through such difficult periods. They could potentially layoff some less experienced people and retain or employ more experienced people until the crisis is over. This could perhaps be one of the explanations to why 57% of all the respondents within the oil and gas industry are within the seven to twenty five years' experience brackets.

Organisations C and D, the relatively newly established indigenous oil and gas companies had higher respondents with fifteen or more years of industry experience than all other organisations. Organisation C had 60% of respondents within the experience group, while Organisation D had 50% respondents. The period covered in this research witnessed a surge in the migration of relatively older employees from the multinational oil companies to the newly established oil companies. These new companies were in need of experienced people to operate their new plants and processes, and the employee layoff due to the reduced oil and gas prices offered these new companies an opportunity to select the laid off employees. In addition, their good incentives were attractive to the experienced people, most of who were pensionable, and could therefore take an early retirement from their current employment to join the new companies, ensuring two different streams of income.

Finally, some of the multinationals sold off a lot of their marginal fields to these new organisations. As part of the sale, contract clauses were inserted to so that the experienced personnel in those fields became part of the new organisations to enable smooth transition. All these perhaps contributed to these new organisations having higher respondents with fifteen or more years of industry experience than all other organisations.

The service organisations (G and H), and to some extent the regional beverage manufacturing organisation (F) had more people with seven or less years of experience than other organisations. Compared to about 20% in C, organisations F, G, and H recorded 60%, 76% and 95.71% for respondents with seven years industry experience or less. This could be attributed to a number of reasons. First, these organisations are mostly owned by individuals with less employee growth and development potentials than the other organisations studied. Secondly, these organisations provide less work incentives and pay than the other organisations. As a result, people often see these organisations as stop gap and short term employments.

Perhaps, it is worth studying further to see the relationship between the high percentages of females in these organisations (71.43% and 76% for G and H respectively), and the much lower percentages of people with less than seven years industry experience (24% and 4.29% for G and H respectively) for these restaurant chains. Finally, organisations *C*, *D*, *F*, and *H* are relatively new organisations with less than 20 years of operation, and as such, may not have had employees that worked that long. Organisations *C and D*, both oil and gas production organisations established within the last 10 years, compensates for this by pulling experienced employees from already existing organisations to form their core employee base. Organisation H, a restaurant chain on the other hand, may not have the strong pull for experienced people as the oil and gas companies; and this might perhaps explain further the 95.71% recorded for respondents with seven years industry experience or less.

The next section shall discus the results based on the responses for each of the five HRO principles.

4.4. Results Based on the Five HRO Principles

This section shall analyse the results based on the each of five principles of high reliability organisations. It shall discus how the organisations and industries perceived the principles and perhaps give an indication on how these perceptions relate with the organisations' performance and culture. As discussed in chapter 3, there are five options for the respondents: 5 - strongly agree; 4 – partially agree; 3 – neither agree nor disagree; 2 – partially disagree; and 1 – strongly disagree. All the questions are positive questions with 5 and 1 indicating the most desirable and least desirable organisational reliability behaviours respectively.

4.4.1. Assessing Preoccupation with Failure

An average of 74.17% of the respondents in Organisation A, chose option five – Strongly agree in the fifteen questions under the preoccupation with failure section. This sharply contrasts with all other organisations in all the industries studied, where the highest percentage of respondents with option 5: strongly agree, were organisations B and C with 7.5% and 7.56% responses respectively.

Table 4.6 – Responses with respect to assessing preoccupation with failure

PREOCCUPATION WITH FAILURE										
	A	B	C	D	E	F	G	H		**Average**
Strongly Agree	74.17	7.50	7.56	1.11	2.80	0.27	0.00	0.00	93.40	**11.68**
Partially Agree	11.33	25.83	20.44	23.56	7.33	3.07	2.53	0.76	94.86	**11.86**
Neither Agree nor Disasgree	9.83	33.67	38.44	35.78	17.33	16.93	13.73	9.52	175.25	**21.91**
Partially Disgree	4.67	17.50	22.22	26.22	24.80	38.93	37.47	40.67	212.48	**26.56**
Strongly Disagree	0.00	15.50	11.33	13.33	47.73	40.80	46.27	49.05	224.01	**28.00**
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00		**100.00**

No respondent in the restaurant chain industry chose option 5: strongly agree, in any of the 15 questions under the preoccupation with failure. Only a handful of respondents of the respondents in the beverage manufacturing industry, 0.27% and 2.8% for F and E respectively, strongly agreed that their organisations exhibited the preoccupation with failure behaviours. Similarly, only 1.11% respondents in organisation D considered their organisation to exhibit the preoccupation with failure behaviours. Contrasting this, over 50% of respondents in all the organisations, except organisation A, strongly or partially disagreed that their organisations exhibit the preoccupation with failure behaviours. This negative response was stronger in the restaurant chain companies G and H, where about 84% and 90% respectively strongly or partially disagreed. Similarly, about 73% and 80% of respondents in organisations E and F respectively, also strongly or partially disagreed.

A look at the interview responses gives some indications to the reasons why most respondents think their organisations were not preoccupied with failure. Most respondents across the industries indicated that their organisations do not encourage incident and near miss reporting. Prominent among the reasons for this in all the industries except the oil and gas, is the fear of punishment for incident or near miss reports. The respondents claimed that people who make mistakes are often victimized, and as such, people would rather hide their errors or potential near misses to secure their jobs. Interviewees in the oil and gas organisations indicated that they report near misses and incidents, but the reports are mostly not treated, nor their recommendations implemented. The consequence of this, they say, is a subsequent reduction in the number and quality of reports. In addition, the interviewees indicated that they do not review activities at intervals to seek potential hotspots. "*You are not allowed to fix it if it is not broken*" one of them said.

In most of the questions under the assessing preoccupation with failure section, there was an obvious gap between the responses of managers and the subordinates. For comments such as "*we do not victimize people who make mistakes",* all the managers in organisation B chose options 3 and above, while all the respondents on the shop floor chose options 2 and below. 70% of the respondents on the shop floor strongly disagreed with the statement. Similarly, for the communication comments such as *"we feel free to talk to our superiors"; our superiors freely talk to us about our problems;* and *"our superiors actively seek out bad news about potential issues",* all the managers in organisation B chose options 3 and above. An average of 63.3% of the managers strongly agreed with these statements, while none of them partially or fully disagreed. On the other hand, all the respondents on the shop floor chose options 3 and below; with 90% of them disagreeing partially or fully. This split is evident in all the organisations. In organisation E, the beverage manufacturing giant, 67% of respondents on the shop floor strongly disagreed with the same set of statements. 91% of all the respondents that are either supervisors or on the shop floor in organisation G, the restaurant chain, disagreed with the statement. The remaining 9% stayed on the fence with the choice of neither agreed nor disagreed.

The same trend was observed among people with different experiences. The responses from the more experienced people within the 25 years and above experience bracket tended to be similar with the responses from people in management position. Perhaps this might be because those in that experience bracket were mostly managers or in senior supervisory positions. This schism indicates a huge dichotomy between the different strata of the organisations, both in terms of communicating, understanding, and implementing the processes required to exhibit the high reliability behaviours in terms of preoccupation with failure.

4.4.2. Assessing Reluctance to Simplify

All the respondents in organisation A agreed, either partially or fully, with all the statements under the reluctance to simplify section. This contrasts sharply with the other organisations surveyed. While organisation B, the international oil and gas organisation, had 38% of the respondents partially or fully agreeing with the statements, organisations C and D, the local oil and gas organisations had 17% and 24% respondents agreeing fully or partially. The beverage manufacturing organisations had a similar response trend at 25% and 15% respectively. For the restaurant chains G and H, only 4% and 3% of respondents respectively agreed fully or partially to the statements.

Table 4.7 – Responses with respect to assessing reluctance to simplify

RELUCTANCE TO SIMPLIFY										
	A	B	C	D	E	F	G	H		**Average**
Strongly Agree	91.46	15.63	0.28	5.56	2.83	2.50	0.00	0.00	118.25	**14.78**
Partially Agree	8.54	22.71	16.94	18.89	23.00	12.83	3.67	3.33	109.92	**13.74**
Neither Agree nor Disasgree	0.00	30.21	30.00	25.56	32.83	28.00	28.50	27.98	203.07	**25.38**
Partially Disgree	0.00	24.79	35.83	28.89	27.17	32.83	41.00	43.93	234.44	**29.31**
Strongly Disagree	0.00	6.67	16.94	21.11	14.17	23.83	26.83	24.76	134.32	**16.79**
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00		**100.00**

Similar to the responses in the assessing preoccupation with failure section, the responses in assessing reluctance to simplify section were highly dichotomous with the managers and senior supervisors largely agreeing with the statements, and the people on the shop floor largely disagreeing. For instance, in response to the statement *"we are encouraged to listen carefully to other viewpoints",* all the managers in organisation B, the international oil and gas organisation, agreed strongly, while no one on the shop floor strongly agreed. This response trend was the similar in all the other oil and gas organisations.

The results of the interviews gave a closer idea of the reasons behind some of the responses. For the statement "*we encourage people to challenge the procedures and processes",* and *we do not victimize people who challenge the norm",* most shop floor respondents in the oil and gas industry and the beverage manufacturing industry explained that such challenges are often considered as challenging the boss. Most of the supervisors and managers would consider it as acts of insubordination when existing norms are challenged by subordinates. For organisations E & F, the beverage manufacturing companies, the interviewees stated that only people in sales would be rewarded for thinking outside the box, as long as the "*thinking*" leads to above target sales. They will still be victimized should sales drop as a result of their "*out of the box thinking*". Furthermore, in response to the statement *"we are not attacked when we report information that could disrupt operations",* no respondent in organisation E, F, G, and H agreed. The oil and gas organisations mostly agreed with the statement, and it would appear they could challenge the norm even if it could disrupt operations.

Almost 90% of supervisors and people on the shop floor in organisations F, G, and H disagreed with the statement *"we value constructive criticism".* The responses from the interviews suggest that the managers and supervisors are unable to distinguish between constructive criticism and insubordination. Finally, in response to the statement "*we reward people who think outside the box",* the interviews in the oil and gas organisations revealed that the rewards are more tilted towards people who spend time reactively fixing breakdowns than on people that proactively prevent things from breaking down. The reactive people are seen to be working and as such are rewarded at the expense of the proactive ones. People therefore spend more time looking for reactive "*do-it-yourself*" initiatives to enhance their perceived potential than on proactive initiatives. In summary, the schism between the leaders and the subordinates found in assessing preoccupation with failure was also highly prevalent in assessing reluctance to simplify.

4.4.3. Assessing Sensitivity to Operations

Organisations in the manufacturing and oil & gas industries performed better in assessing sensitivity to operations than in all other HRO principles. Only organisation F, the smaller and localized beverage manufacturing organisation had less than 30% respondents agreeing with the assessing sensitivity to operations statements. An average of 47%, 33%, 52%, and 33% respondents in organisations B, C, D, and E respectively agreed, either strongly or partially to the assessing sensitivity to operations statements. This could perhaps be as a result of the perception of the industry as being more hazardous than the restaurant chains. In the restaurant chains on the other hand, only about 7.5% of the combined respondents agreed with the assessing sensitivity to operations statements.

Table 4.8 – Responses with respect to assessing sensitivity to operations

SENSITIVITY TO OPERATIONS										
Strongly Agree	A	B	C	D	E	F	G	H		**Average**
Strongly Agree	86.82	19.77	8.48	20.00	8.73	5.64	0.18	0.91	150.53	**18.82**
Partially Agree	9.09	27.05	24.85	32.12	23.82	18.36	6.91	7.14	149.34	**18.67**
Neither Agree nor Disasgree	2.27	32.50	35.76	20.30	28.18	24.91	31.45	26.88	202.26	**25.28**
Partially Disgree	1.82	15.68	25.15	16.97	24.91	28.55	38.36	40.00	191.44	**23.93**
Strongly Disagree	0.00	5.00	5.76	10.61	14.36	22.55	23.09	25.06	106.43	**13.30**
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00		**100.00**

Similar to the other HRO principles already discussed, there is also a schism between the perceptions and realities as observed by people in different strata of the organisations. People in management appeared to have positive perceptions about the direction of the organisations in terms of their sensitivity to operations. The mid-level supervisors and people on the shop floor on the other hand appeared to have an alternative perception about the nature of reality with respect to the organisations' sensitivity to operations. For instance, whereas 100% of the managers in organisation B strongly agreed to the statement *"people have the discretion to resolve unexpected frontline problems without deferring to leadership"*, 100% of the respondents on the shop floor did not agree.

Apart from oil and gas organisations B and D, all the others performed considerably low in the statements about discretion to take responsibility without deferring to management. All the respondents in the restaurant chain disagreed with the statements *"people have the discretion to resolve unexpected frontline problems without deferring to leadership"* and *"everyone is expected to take decision, such as operations shutdown to forestall catastrophic failure".* A similar result was obtained with statements about open communication between frontline and management.

The interviews revealed the possible explanation to some of these observations. When confronted with the statement *"our managers constantly monitor our day to day activities*" the management staff mostly considered it a positive behaviour to monitor the daily activities of the staff, whereas the frontline staff and mid-level supervisors considered such monitoring as an act of micro management.

Considering the statement *"someone with authority is readily available to frontline for prompt decision making"*, most interviewees in almost all the organisations confirmed that there would always be someone with authority available to the frontline. They however disagreed that that person with authority's ability to take some decisions without deferring to the management. Similarly, considering the statement *"everyone is expected to take decision, such as operations shutdown to forestall catastrophic failure"*, interviewees in the oil and gas organisations, and the manufacturing organisations, accepted that while the procedure might clearly empower everyone to shutdown to forestall potential catastrophic failure; executing such procedures could potentially lead to loss of jobs. One of the respondents cited the case of a shutdown due to potential catastrophic threat that was later found to be a false alarm. The employee that initiated the emergency shutdown was victimized, considered incompetent, and later released from the organisation. As a result, people would rather wait for clear instruction from management to initiate a shutdown, even in the face of potentially catastrophic failures.

In summary, the oil and gas organisations appeared to be more sensitive to operations than the manufacturing organisations, which in turn appeared to be more sensitive to operations than the restaurant chains. The schism in perspectives between the management and frontline staff over their perception of reality, as observed in the other HRO principles, is also clearly evident in assessing sensitivity to operations.

4.4.4. Assessing Commitment to Resilience

At about 96%, the respondents from organisation A consider their organisation to be strongly committed to resilience. The interviews in this organisation described how in the face of a potentially catastrophic spill that discharged about 100,000 litres of heavy crude and diluent into the river, the clean-up of which cost the organisation almost $110M, the organisation remained resilient. The organisation mindfully pulled human and material resources together, worked with existing regulations, created new relationships, and collaboratively managed the catastrophe, learnt from it, and repositioned for better competitiveness.

About 69% of respondents in organisation B, the international oil and gas organisation agreed with the assessing commitment to resilience statements. The number reduced to between 42% and 29% in the local oil & gas organisations and the manufacturing organisations. 60% and 77% of respondents in organisations G and H respectively, the restaurant chains, disagreed with the assessing commitment to resilience statements.

Table 4.9 – Responses with respect to assessing commitment to resilience

COMMITMENT TO RESILIENCE										
	A	B	C	D	E	F	G	H		**Average**
Strongly Agree	95.63	30.63	5.00	16.39	13.50	6.33	0.17	0.48	168.12	**21.01**
Partially Agree	2.50	37.92	28.33	15.28	28.17	22.33	13.33	5.83	153.69	**19.21**
Neither Agree nor Disasgree	1.46	21.25	41.94	36.11	39.50	25.17	26.00	16.67	208.10	**26.01**
Partially Disgree	0.42	8.33	17.50	26.11	18.17	29.00	34.67	37.14	171.34	**21.42**
Strongly Disagree	0.00	1.88	7.22	6.11	0.67	17.17	25.83	39.88	98.76	**12.34**
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00		**100.00**

As observed in the other HRO principles, the difference between the organisations' performance as viewed by the management staff and the frontline was also clearly evident. A common thread during the interviews was the fact that although the procedures and plans may be well defined, most people may not be aware due to poor effort by management to cascade them and inspire people to own the procedures and plans. This corresponds with the responses from the questionnaires. For instance, in responding to the statements *"we have well defined emergency response plans"*, and *"most people are aware of the details of the emergency response plans"*, respondents in organisation H that chose option 3 in the former, would choose option 2 in the later. This was also evident in the statement *"we have well defined contingency plans"*, and *"most people are aware of the details of the contingency plans"*.

The oil and gas organisations mostly agreed that they conduct regular drills to enhance their preparedness in case of unexpected problems, whereas all the other organisations mostly disagreed. All the respondents in the restaurant chains disagreed to the statement *"we conduct regular drills to enhance preparedness in case of unexpected problems"* with almost 60% disagreeing strongly. Some respondents interviewed in these organisations claimed to never having experienced an emergency drill, with some not having heard the term "emergency drill" before.

In summary, the oil and gas organisations appeared to be more committed to resilience than the other organisations. The restaurant chains appeared to be the least committed to resilience among all the organisations surveyed.

4.4.5. Assessing Deference to Expertise

Apart from organisation A where about 97% of the respondents strongly agreed, only organisation D, the new indigenous oil and gas organisation had above 7% of the respondents strongly agree to the deference to expertise statements. The interviews showed that organisation D employed the bulk of its employees from the highly experienced personnel from the international oil organisations that had just retired, were approaching retirement, or were at the peak of their careers. This suggests that expertise for emergencies could be potentially readily available and the organisation could potentially leverage on the experience pool than on rank to steer them through their formative stages. However, in all of these organisations, including D, more than 50% of respondents disagreed to the assessing deference to expertise statements. The numbers were as high as 76% and 66% in the restaurant chain organisations H and G respectively, 54% and 57% in the manufacturing organisations E and F respectively, and 51%, 67%, and 60% in the oil and gas organisations D, C, and B respectively.

Table 4.10 – Responses with respect to assessing deference to expertise

DEFERENCE TO EXPERTISE										
	A	B	C	D	E	F	G	H		**Average**
Strongly Agree	96.88	6.25	1.67	11.25	4.00	6.75	0.50	0.00	127.29	**15.91**
Partially Agree	3.13	15.63	12.08	17.08	16.50	17.75	11.25	1.61	95.02	**11.88**
Neither Agree nor Disasgree	0.00	17.81	19.17	20.83	22.50	21.75	22.75	22.50	147.31	**18.41**
Partially Disgree	0.00	25.31	26.25	23.75	24.75	23.75	26.00	32.50	182.31	**22.79**
Strongly Disagree	0.00	35.00	40.83	27.08	32.25	30.00	39.50	43.39	248.06	**31.01**
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00		**100.00**

Similar to the other HRO principles discussed, the schism between the managers' perspectives and perspectives of people on the shop floor remains wide. While most managers continued with their mostly positive perspective about the organisations' deference to expertise, the most responses from people on the shop floor were mostly negative. Generally however, responses from most people across all the organisations were generally negative with respect to expertise over rank. For instance, almost all respondents in organisation B disagreed to the statement *"people in the organisation value expertise and experience over rank",* and *"we are encouraged to take expert decisions irrespective of hierarchy",* and *"in an emergency, the most experienced in* *that emergency takes the lead".* The same response was observed in all the other organisations.

The results from the interviews conducted helped to understand the reasons behind some of the results. Responding to the statement *"people respect the nature of one another's jobs"*, the most respondent in management positions across the organisations except the restaurant chains mostly agreed. The people on the shop floor however mostly disagreed. The people interviewed cited a class distinction between graduate positions and low level shop floor positions. A security man or a driver is made to feel inferior to the engineer or the supervisor, despite the fact that all the roles contribute to the overall output of the organisation. The manager would therefore not yield to the security man during a security emergency, and would be expected to take charge despite obvious lack of experience on security issues. Similarly, most interviewees across the organisations conceded that they are only committed to doing their jobs to the extent that it is their major source of livelihood. They have not been inspired to become committed to their jobs, rather are kept in check by fear of job loss and annual appraisals.

In summary, most of the respondents and the interviewees agreed that decisions during emergencies are based mostly on hierarchical positions rather than on expertise. This was a common theme across the organisations.

4.5. Chapter Summary

This chapter has described the results obtained from the surveys and the interviews. It compared and contrasted the results obtained from organisations with respect to each of the five HRO principles. It concluded that there was a dichotomy between the perceptions of people in different strata of the organisation with regards to how their organisations perceive the high reliability organisation behaviours. It also observed the same schism among the various experience categories within the organisation. It assessed the behaviours of the organisations in terms of HRO principles and described the reasons behind some of those behaviours.

The next chapter shall use these results to develop the framework for measuring the reliability of the organisations. It shall introduce the organisational reliability maturity model and the organisational reliability framework. It shall describe how to use the model and the framework to assess organisations. Furthermore, the chapter shall describe how to use the framework and model to compare and benchmark organisations. Finally, the chapter shall develop improvement processes based on the organisational reliability maturity model and framework.

CHAPTER FIVE

Organisational Reliability Maturity Model (ORM^2) and Framework (FORM)

5.1 Introduction

Chapter four presented the results obtained from the data collection process. It described how the low response rate from the initial online survey instrument made it revert to the conventional hard paper survey. It proposed some possible reasons for the initial low response rate and described how these were overcome using the paper surveys to obtain an eventual 93.75% response rate. Furthermore, the chapter discussed the demographic information of the various categories of respondents. The demographic information included the gender spread among the various respondents in the different organisations, their roles and responsibilities, and their years of experience within their respective industries. The chapter compared the various organisations and industries with respect to the different demographic information. This was done in order to attempt to gain some perspectives about the influence of organisational and industry diversity on the nature of responses. Finally the chapter grouped the results into the five HRO principles and analysed how the organisations and industries perceived the different HRO behaviours. It concluded by analysing how these HRO behaviours were influenced by the different demographic divisions.

Chapter five shall discuss the results, and them to develop a framework for measuring the reliability of organisations in answer to the first research question *"... can the reliability of organisations be measured?"* Having answered this question, the chapter shall attempt to answer the second research question *"can these measurements help diverse organisations become more mature?"* It shall describe how the framework for measuring organisational reliability could be used to assess the health of organisations in terms of organisational reliability maturity. Additionally, Chapter 5 shall describe how the framework could be developed to compare and benchmark organisations against desired organisational reliability standards or against recognized industry standards. Finally, the chapter shall illustrate how the framework could be developed to help organisations improve their maturity in terms of organisational reliability.

5.2 Introducing the Organisational Reliability Maturity Model (ORM^2)

The first research question aims to investigate the extent to which the reliability of organisations can be measured. A lot has been said and written about high reliability organisations and a number of organisations have attempted to organise themselves for reliability with varying degrees of successes and failures. At this point, those perceptions of successes and failures are at best subjective. Each organisation has operated in silos and there has been no coordinated effort to standardize the expected criteria towards organising for reliability. There has also been no effort to develop a standardized stepwise approach towards achieving organisational reliability. The gains of organising for reliability have been highlighted in earlier chapters and cannot be overstated. However, as stated earlier in chapter one, "*you can't manage what you can't measure*", or as some others choose to put it, "*you can't improve what you can't measure*". For an organisation to begin to take steps towards improvement, it must first develop a framework for measuring and understanding its prevailing statuses. It must establish a baseline from which it could launch its improvement or sustainability initiatives.

The Organisational Reliability Maturity Model (ORM^2) has been designed to provide baseline measurement for organisations to assess their current statuses in terms of organisational reliability maturity. It is a five stage maturity model similar to Crosby's (1979) quality management maturity model. The five levels are *silent, starter, stable, sustain, and summit*, with *silent* being the lowest maturity level (level 1) and *summit* being the highest maturity level (level 5). This could also be referred to as the 5S model of organisational reliability maturity since all the letters from each of the 5 maturity levels begins with an "S". ORM^2 comprises of 25 boxes, with each box containing 25 sets of organisational reliability behaviours. The maturity levels are on the x-axis with incremental maturity behaviours as the boxes progress towards the right hand side. The y-axis represents the five HRO principles. This means that for each HRO principle, there are five sets of organisational reliability behaviours, with incremental improvements as the levels increase from level 1 (*silent)* towards level 5 (*summit).*

The organisational reliability behaviours used in ORM^2 leverages on four major sources. The first source is the work of Weick & Sutcliffe (2007; 2015), that identified some behaviours expected from high reliability organisations. The second source is the experience of this researcher, obtained from over twenty years working in the petroleum and manufacturing industries. The third source is the combined experiences of the research supervisors, which includes over sixty years working across diverse industries including the academia, oil and gas industry, manufacturing, nuclear, automobiles, and the aeronautics industries. The final source is the combined experiences of the some industry experts interviewed during the course of research design.

ORM^2 is designed to track the maturity of organisations through five levels of maturity. It begins with a "*silent"* period (level 1), a passive period characterised by lack of standardized processes, poor communication, inadequate procedures, combative and punitive relationships, and a false sense of safety and security – an *"if it ain't broke, don't fix it mentality".* Considering the preoccupation with failure HRO principle, the level 1 (*silent)* behaviours are characterised by a deep blame culture where people would be punished for causing incidents, and as a result, near misses and failures are not reported for fear of the punitive measures. There is usually a blind optimism that incidents would not occur, and when they do, the perception would be that it must have been caused by someone. The blame culture is also highlighted in the reluctance to simplify principle, where scepticism is frowned upon and people who challenge the norm are regarded as disruptors and are victimized. Table 5.1 shows ORM^2 in details. Each maturity level is shown on a different column and the rows indicate the corresponding HRO principles.

As the organisation begins to realise the dangers of remaining in a "*silent"* period, it begins to develop some processes. It also begins to take steps towards improving communication, developing procedures, trainings, and competence development exercises. It begins to encourage near miss and incident reporting. The organisation at this stage is considered a *"starter"* and is said to have begun its teething process. They begin to develop the awareness that skeptics and people who report near misses and incidents should not be punished. They begin to understand the need to develop meetings, documentations, reports, procedures, and standardized processes. They begin to recognise the need for competence development and trainings. It must be pointed out that although the organisations in level 2 *start* to recognise and sometimes *start* to develop these processes, the implementation at this point is lethargic at best.

As the organisations progress through the maturity cycle, they would get to a point where their processes and procedures become fully developed. At this point, everyone understands and works with the processes with near mechanical precision. Assessments of level 3 would mostly be to check how *"stable"* the organisations are: the availability of the processes, the robustness of the processes, and the extent to which people are following the processes. People comply because they have to, and failure to comply would often attract severe consequences. In most cases, the organisation would have slogans such as *"if you decide not to comply with the process, you have decided not to work with us".* The emphasis is clear: comply or be sacked, and people are therefore compelled to comply. Employees would attend meetings at regular times because they have to, attend trainings because they have to, and participate in appraisals because they must. The organisations would be considered to be at a *"stable"* stage, with fully standardized processes, and the people working with clockwork efficiency.

At level 4, *"sustain",* the people are no longer compelled to follow the laid out procedures and processes, but would begin to understand and agree with the reasons for the processes and procedures and actually begin to take the initiatives to own the process. They begin to see themselves as stakeholders to help sustain the process. An emergency drill would no longer be seen as a necessary burden to please the leaders, but as a necessary tool towards personal and organisational resilience. People begin to own their learning and development and would begin to see feedback as a positive process for organisational and personal improvement. The organisation would begin to proactively feed lessons learned back into the process to improve it. The organisations begin to value and reward sceptics and those that think outside the box, and meetings would begin to become useful avenues for improvement discussions. The key word in the *"sustain"* level is "proactive": people begin to take proactive initiatives to sustain the processes.

The final level is the *"summit",* a stage where the relationships between the leaders and the led, and among the people in the organisation becomes very respectful, people actively seek 360 degrees feedback and accept the objective feedback as a performance improvement opportunity. People are mindful of the operations and take proactive decisions to safeguard and improve the process. Everyone works proactively without coercion, with a common purpose to improve and sustain the organisation. The key word with this level is "*ownership"*: people begin to own the processes, which enhances further proactive actions. A process operator would "own" the plant and would passionately perform his operator rounds, diligently seeking out "potential hot spots" for proactive actions.

Table 5.1 spells out the key behaviours in each of the five maturity levels for each of the five high reliability organisations principle. The next subsection shall introduce the Framework for Organisational Reliability Maturity (FORM).

Table 5.1: Organisational Reliability Maturity Model (ORM^2) – The 5S Model

ORGANIZATIONAL RELIABILITY MATURITY MODEL					
	Level 1 (Silent)	Level 2 (Starter)	Level 3 (Stable)	Level 4 (Sustain)	Level 5 (Summit)
Preoccupation with Failure	Failure/Near Misses are not reported. Punishment for people that cause incidents. Management difficult to approach. Continuous mindset that failure will not happen. If a failure occurs, someone is always to blame.	Failure/Near misses sometimes reported and rectified. Root causes may not be identified. People that cause incidents are perceived as incompetent but may not be punished. Some communication with a few people.	Failure/Near misses reporting process exists and is generally enforced. Root causes identified. People often blamed. Superiors communicates with frontline to give clear instructions.	Failure/Near misses reported. Root causes identified and people not blamed. Clear and open communications. Worst case scenarios considered in planning. Lessons learned documented.	Failure/Near Miss identified, categorized, documented. Root causes identified. Root causes resolved with no blame on people. Lessons learned reviewed periodically and used to improve the system. People that report near misses/failure are actively rewarded. Superiors actively seek out bad news. Clear and open communication between superiors and front line staff. Planning considers worst case scenarios. Continuous reviews to seek out hot spots.
Reluctance to Simplify	Skeptics and people that challenge the norm are mostly victimized and punished as disruptors.	Skeptics and people who challenge the norm may not be punished, but may be viewed negatively	A process for challenging the process exists. It is ok to challenge the norm. Implementation may be delayed by layers of bureaucracy.	Views from skeptics and out of the box thinkers are respected and often implemented by management.	Management actively creates forums for people to challenge the norm and out of the box thinkers are rewarded.
Sensitivity to Operations	Meetings are rare without quality: no focus on long/short term team/organization. Leaders are unaware of frontline issues. People generally do not understand jobs outside their specialty. Feedback is viewed as a process of negative reinforcement. There is no feedback process. People are generally overworked and stressed out. Complaints are viewed as insubordination and could be punished	Occasional meetings with no defined terms of reference. Leaders request for and receive reports as desired. People may understand jobs outside their competencies, but rarely get involved. People generally do not care about feedback. Might receive one during annual appraisal. There are occasional breaks to relieve work stress	Regular Meetings with defined terms of reference. A clearly defined work report process exists and is enforced. A formal process exists and is generally enforced for people to learn jobs outside their competencies and get involved. A feedback process exists and is generally enforced. There is a process to manage workloads	Regular Meetings are regular with defined terms of reference and individual roles/responsibilities. Leaders generally get involved in the frontline day to day activities and therefore receive first hand reports. People are generally willing to get involved in jobs outside their competencies and the opportunities exist for them to do so. People generally give and receive feedback at defined times without coercion. Leaders continuously monitor workloads and add resources as required.	Meetings are regular with defined terms of reference and individual roles/responsibilities. It is clear how everyone's roles fits into the big picture. Frontline and leaders are generally free with one another and interact freely in day to day operations. People are rewarded for getting involved in jobs outside their competencies. People actively seek feedback, and perceive 360* feedback as constructive exercises. Leaders continuously work with staff to monitor workloads and would collectively determine need for additional resources.
Commitment to Resilience	The company does not organize/sponsor trainings. Competencies and skills are not assessed. There are no emergency response and contingency plans.	Trainings exist, but only used to reward favoured staff. Individual leaders assess competencies and skills in their own way. There are emergency response and contingency plans but people are generally not aware of them. Drills are regarded as nuisance.	There is a formalized training and competence/skills assessment for all staff and the plan is generally enforced. Emergency drills are done and people are mandated to participate. People are generally mandated to understand the emergency response/contingency plans	Leaders and staff work together to identify training and development gaps and close them. Competence assessment is an ongoing process and feedback is constructive. People actively seek to understand and review emergency response and contingency plans. People regard drills as ways to potentially save lives	People generally have more than enough skills for their jobs and to act during emergencies. Competence and skills assessment is a proactive process. Emergency response and contingency plans are robust and implementation is a shared responsibility among all staff. Everyone trusts one another and relies on one another during emergencies.
Deference to Expertise	In an emergency, the most senior person takes responsibility irrespective experience. It is difficult to know who has the most expertise for each emergency.	People generally know who has the most expertise during an emergency. Hierarchical rank takes precedent during emergencies. The most senior person feels insulted if not in charge during emergencies.	There is a formal process to determine who takes responsibility during each emergency.	The most senior person yields responsibility to the person with the most expertise for during each emergency. The expert accepts the responsibility professionally and yields back after the emergency. Expertise for all emergencies is readily available	There is a mutual respect for one another's jobs. No job is considered more important than the other. People are encouraged to take expert decisions irrespective of hierarchy during emergencies. People feel responsible until problems are resolved.

5.3 Introducing the Framework for Organisational Reliability Maturity (FORM)

This research has developed the Framework for Organisational Reliability Maturity (FORM) to track the responsiveness of the organisations with respect to each of the five HRO principles. The framework performs four basic functions. First, it is a health check that assesses the current maturity level of organisations. Secondly, the framework could use the current organisational reliability behaviours to predict the future direction the organisation could potentially go. This could indicate if the organisation would improve or retrogress. The third function is the ability of the framework to benchmark organisations against desired maturity standards, either internally or externally. The final function lies in the ability of the framework to be used in conjunction with the organisational reliability maturity model to enhance organisational learning, and suggest improvement enhancing behaviours, as well as potential improvement limiting behaviours.

To develop the Framework for Organisational Reliability Maturity (FORM), a survey must first be conducted in the target organisations using the ORM^2. The questionnaire in appendix 3 and the interview questions in appendix 4 have been developed for use in this survey. They have been field tested in eight different organisations with similar trends and are therefore validated. This could be scaled or modified to suit the organisational context. This research was conducted using purposive sampling method. Results from the survey is analysed and summarised into the FORM table as shown in table 5.2 below.

Table 5.2: Framework for Organisational Reliability Maturity (FORM)

COMPANY C (OIL &GAS))							
Level	Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise	**Average Score**	Pull
5	7.56	0.28	8.48	5.00	1.67	**4.60**	0.14
4	20.44	16.94	24.85	28.33	12.08	**20.53**	0.62
3	38.44	30.00	35.76	41.94	19.17	**33.06**	0.00
2	22.22	35.83	25.15	17.50	26.25	**25.39**	0.77
1	11.33	16.94	5.76	7.22	40.83	**16.42**	0.50

Table 5.2 shows the summarised FORM table for company C. The five HRO principles are mapped against five levels that correspond with the five maturity levels on the Organisational Reliability Maturity Model (ORM^2). Level 1 is the least mature, while level 5 is the most mature. All numbers under the HRO principles are percentages obtained from the average scores in the survey. For instance, the table shows that an average of 7.56% of all the respondents in company C selected options that indicate their organisation to be at level 5 in preoccupation with failure. The *average score* column is a simple average of responses from the five HRO principles in each maturity level. For instance, 4.6% is a simple average of the respondents that selected level 5 behaviours in all the five HRO principles put together.

For the sake of this research, the principles have been given equal weighting. Future research might explore different weighting scales for different organisations in specific industries in line with prevailing priorities within those industries or organisations. The maturity of the organisation is determined by the level with the highest average score. In Table 5.2, 33.06% is the highest average score; therefore company C is considered to be at maturity level 3 (*stable).* The performance of the organisation in each of the five principles will give an indication of how much resources should be committed to one principle over the others to achieve improvement. Company C performed the least in the deference to expertise and reluctance to simplify HRO principles. It would therefore invest more to improve these two principles than the other three in its drive to improve the overall organisational maturity.

The last column on the table is the *pull*, and it indicates the maturity level where the organisation has the most probability of slipping into given prevailing conditions. *Pull* (P) is a simple probability:

$$P = 1 - (R - Ri)/R \tag{2}$$

R is the highest average score: the score for the assigned maturity level, while Ri is the average score for the maturity level under consideration and is unique for each maturity level. For Table 5.2 above, the organisation is at maturity level 3 (*Stable)* with the highest average score at 33.06%; R is therefore 33.06. Considering maturity level 5 (*summit)*, the average score *Ri* is 4.6%. Substituting *R* and *Ri* the pull calculation above, the pull towards level 5 (*summit)* will be 0.14. The same process is applied to the other maturity levels to obtain their pull. From these calculations, the pull is highest towards maturity level 2 (*starter)* at 0.77. This means that the organisation has the highest probability of slipping into level 2 (*starter)* from its current maturity level 3 (*stable)*, given its prevailing organisational reliability behaviours. There is an equally strong pull towards level 1(*silent)* at 0.50 and organisation must be careful not only to slide into level 2 *(starter)*, but could potentially move further down towards level 1(*silent)*. 0.5 is considered the *low pull,* while 0.77 is considered the *high pull*. The framework shows that the higher the pull, the more the probability of the organisation to move towards that maturity level.

In addition to applying the pull to the entire organisation, it can be applied to each individual HRO principle to determine its potential risk factors to the organisation.

Table 5.3: Framework for Organisational Reliability Maturity (FORM) for individual HRO principles using Company C

FRAMEWORK FOR ORGANISATIONAL RELIABILITY MATURITY					
COMPANY C (OIL &GAS))					
Level	Preoccupation with Failure	Pull	Commitment to Resilience	Pull	Average Pull for all 5 Principles
5	7.56	0.20	5.00	0.12	0.11
4	20.44	0.53	28.33	0.68	0.60
3	38.44	0.00	41.94	0.00	0.00
2	22.22	0.58	17.50	0.42	0.77
1	11.33	0.29	7.22	0.17	0.50

In table 5.3 above, the pull is applied to the preoccupation to failure and the commitment to resilience principles. Company C is at maturity level 3 (*stable)* on both principles but is being pulled differently on both. It is strongly pulled at 0.58 down towards level 2 (*starter)* in preoccupation to failure, and at 0.68 up towards level 4 (*sustain)* in commitment to resilience. The pull in this instance could help the organisation prioritize resources to achieve a higher maturity level. The sum of all the values in each HRO principle, as well as the sum of the average scores should always be 100%. All numbers, except the *pull,* are percentages of responses. The next four sections shall discuss how the framework for organisational reliability maturity could be used by organisations to understand their current maturity levels; predict their potential future maturity levels given current behaviours given current practices; benchmark against desired standards; and improve themselves.

5.4 Applying the Framework for Organisational Reliability Maturity (FORM) to assess organisations.

Table 5.4 shows company H to be at maturity level 2 (*starter)* with an average score of 38.85%. It also shows the individual strengths and weaknesses of the company H with respect to each of the five HRO principles. For instance, it shows that although the company is at maturity level 2 (*starter),* it is at level 1 (*silent)* in preoccupation with failure, commitment to resilience, and deference to expertise behaviours. The framework therefore helps organisations to perform a health check. Company H could at a glance, understand that there is a very thin line between its level 2 and level 1 positions and as such could easily slide from one to the other. It would also understand that performances in preoccupation with failure, commitment to resilience, and deference to expertise are driving the organisational reliability down.

Table 5.4: Framework for Organisational Reliability Framework (FORM) for Company H

FRAMEWORK FOR ORGANISATIONAL RELIABILITY							
COMPANY H (RESTAURANT CHAIN)							
Level	Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise	**Average Score**	Pull
5	0.00	0.00	0.91	0.48	0.00	**0.28**	0.01
4	0.76	3.33	7.14	5.83	1.61	**3.74**	0.10
3	9.52	27.98	26.88	16.67	22.50	**20.71**	0.53
2	40.67	43.93	40.00	37.14	32.50	**38.85**	0.00
1	49.05	24.76	25.06	39.88	43.39	**36.43**	0.94

Table 5.5 below shows the framework table for company E. From the table, company E would understand that it is currently on maturity level 3. It would also understand that the pulls towards level 2 and level 1 are quite high at 0.82 and 0.77 respectively. This would suggest to company E that although they are on maturity level 3 (*stable),* their current practices and behaviours could see them potentially slide towards level 2 and 1. The framework would also tell company E it is stable in its commitment to resilience and sensitivity to operations, and reluctance to simplify behaviours, but very poor in its preoccupation with failure and deference to expertise behaviours.

Table 5.5: Framework for Organisational Reliability Framework (FORM) for Company E

COMPANY E (BEVERAGE MANUFACTURING)							
Level	Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise	**Average Score**	Pull
5	2.80	2.83	8.73	13.50	4.00	**6.37**	0.22
4	7.33	23.00	23.82	28.17	16.50	**19.76**	0.69
3	17.33	32.83	28.18	39.50	24.75	**28.52**	0.00
2	24.80	27.17	24.91	18.17	22.50	**23.51**	0.82
1	47.73	14.17	14.36	0.67	32.25	**21.84**	0.77

Armed with this knowledge, the organisations could therefore begin to develop improvement measures. It is only organisations that can measure and understand their current position that can use these understanding as a pedestal upon which to seek organisational learning and performance improvement.

5.5 Applying the Framework for Organisational Reliability Maturity (FORM) to Predict the Future

Being able to predict the future is the elusive crystal ball that all have desired and few have achieved. This framework leverages on the organisational reliability maturity model (ORM^2) and the identified current position of the organisation, to predict how the organisation could potentially behave in future given current operating conditions. Perhaps, understanding such future behaviour could potentially become the key to incident prevention.

Company G is a relatively new restaurant chain with operations in over 20 locations and is a popular destination for young families and children. Catastrophic failures could result through batch food poisoning and playground equipment failure. Using company G as an example, the organisation currently on maturity level 2 (*starter)*, could potentially slide down to maturity level 1(*silent)* if it continues with its current behavioural trends. The pull of 0.91 towards level 1 (*silent)* is very strong and would more likely tilt the organisation towards level 1 than improve towards level 3 where the pull is 0.69.

Table 5.6: Framework for Organisational Reliability Framework (FORM) for Company G

COMPANY G (RESTAURANT CHAIN)							
Level	Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise	**Average Score**	Pull
5	0.00	0.00	0.18	0.17	0.50	**0.17**	0.00
4	2.53	3.67	6.91	13.33	11.25	**7.54**	0.21
3	13.73	28.50	31.45	26.00	22.75	**24.49**	0.69
2	37.47	41.00	38.36	34.67	26.00	**35.50**	0.00
1	46.27	26.83	23.09	25.83	39.50	**32.30**	0.91

This predictive feature is much more useful when utilized at the level of the individual HRO principles. The organisation is already at the lowest level in its preoccupation with failure and deference to expertise. This means that near misses and incidents are not reported, and that the communication line between management and frontline is very difficult at best. It also means that expertise is often sacrificed on the altar of hierarchy.

Combining these behaviours suggests that a disaster could be imminent. The potential for food poisoning or equipment failure is not only very high; the ability of the organisation to manage the disaster when it occurs is very low. On the other hand, the organisation could potentially improve in their reluctance to simplify, sensitivity to operations, and commitment to resilience. It could be predicted to improve level 3 (*stable)* in its reluctance to simplify, sensitivity to operations, and commitment to resilience. The pull towards levels 3 and 1 in commitment to resilience are too similar that the correct prediction might be too close to call between improving towards level 3, and retrogressing towards level 1. In such instance, it would be safe to assume a worst case scenario.

The same process could be applied to each of the organisations to predict their potential future positions. Company C is an indigenous oil and gas company established within the last 3 to 10 years. It has substantial interests in land and swamp oil and gas fields and production facilities, and is considered to be a major player in the oil and gas sector. Oil spills and gas leaks are major sources of disasters that could result in catastrophic events such as explosions, fire, and environmental pollution.

Table 5.7: Framework for Organisational Reliability Framework (FORM) for Company C

COMPANY C (OIL &GAS))							
Level	Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise	**Average Score**	Pull
5	7.56	0.28	8.48	5.00	1.67	**4.60**	0.14
4	20.44	16.94	24.85	28.33	12.08	**20.53**	0.62
3	38.44	30.00	35.76	41.94	19.17	**33.06**	0.00
2	22.22	35.83	25.15	17.50	26.25	**25.39**	0.77
1	11.33	16.94	5.76	7.22	40.83	**16.42**	0.50

Company C is currently on maturity level 3 (*stable)*, and could potentially slide down to maturity level 2 (*starter)* if it continues with its current behavioural trends. The pull of 0.77 towards level 2 (*starter)* is very stronger than the others and would more likely tilt the organisation towards level 2 than improve towards level 4 where the pull is 0.62. Besides that, there is also an increased pressure towards a decline with an additional pull of 0.5 towards level 1 (*silent*). This would indicate that company C could potentially decline if improvement actions are not taken.

The organisation is already at the lowest level in its deference to expertise, which would suggest that the organisation either does not have the expertise to respond to catastrophic failures or does not defer to the expertise available during emergencies. The organisation is at level 2 in its reluctance to simplify but is in a good position to improve towards level 3. This means that although sceptics and people who challenge the norm are increasingly no longer being punished, negative perceptions about them still widely exist. The organisation however is beginning to standardize the processes for challenging the processes and procedures. Furthermore, the organisation is at level 3 (*stable)* in its preoccupation with failure, sensitivity to operations, and commitment to resilience. Given the current behaviours, company C could be predicted to improve towards level 2 (*sustain*) in its commitment to resilience, while it would be predicted to potentially regress to level 2 (*starter*) in both its preoccupation with failure and sensitivity to operations. Level 2 behaviours mean that there is no standardised process for incident and near miss reporting, root causes are not identified and people are still blamed for failures and could sometimes be punished or mostly victimized. It also means that formalized trainings, competence development and competence assessment are not available. Furthermore, it means that people are not generally aware of emergency response and contingency plans and are therefore not equipped to respond to emergencies. Combining these also would predict that disasters could occur, and when it does, the organisation would neither be able to contain it nor be resilient enough to reorganise for future competitiveness.

Without previous data, it might be challenging to show if the pull is towards improvement or away from improvement. For instance, the average pull of 0.91 in company C could indicate that the current reliability behaviours are pulling the organisation down towards level 1. However, if an earlier study had shown a pull of 0.99 towards level 1and a lower pull of 0.61 towards level 3, the organisation could then be said to be actually improving towards level 3. This means that for an effective prediction, the baseline measurements must be established. This baseline would become the benchmark to use in gauging the improvements or decline of the organisation. The next section shall discus this baseline measurement and its importance in benchmarking.

5.6 Applying the Framework for Organisational Reliability Maturity (FORM) to Benchmark Organisations

Another important feature of the framework for organisational reliability maturity (FORM) is the ability to benchmark organisations internally and externally. It could be used by organisations to benchmark against a desired maturity level at each point in time; against HROs; against organisational peers; or for internal benchmarking. For benchmarking to be effective, baselines must be established. A good way to do this would be to use the best in class behaviours expected from high reliability organisations. These behaviours are found in the maturity level 5 on the organisational reliability maturity model (ORM^2). Using the framework as described in section 5.4, organisations deploying this for benchmarking purposes would first establish their current position based on behaviours identified in their survey. It must be noted that the methods of data collection is not only limited to surveys as adopted by this research. Other methods of data collection such as case studies and action research could be adopted by organisations based on their organisational realities. As soon as the current position is established, it would be documented to form their baseline behaviours. The success or failure of the adoption and implementation of the framework would thereafter be determined by variance in the behaviours at the baseline, and at each point in time. Organisations might choose periodic time frames of 6 months, 1 year, 2 years, or 5 years as desired; or could choose periodic time frames as could be stipulated by organisational standards for conducting health checks. Having established their individual baseline behaviours, the organisations would thereafter identify a standard to benchmark against. This could be against level 5 behaviours, against identified HROs, against peers, or against its previously identified behaviours, and against itself in interdepartmental benchmarks.

5.6.1. Benchmarking against best in class organisations

This discussion assumes that company A is a high reliability organisation based on its behaviours on all the HRO principles. Table 5.8 gives a visual comparison of the maturity levels and the individual pull for the 8 organisations surveyed. The values were extracted from the summary of surveys for each of the organisation. This is a high level benchmark using the average maturity behaviours.

Table 5.8: High level comparison of organisational maturity

COMPARING THE MATURITY OF THE ORGANIZATIONS					
ORGANIZATIONS	SILENT	STARTER	STABLE	SUSTAIN	SUMMIT
COMPANY A					
COMPANY B	0.47	0.68	ML	0.95	0.59
COMPANY C	0.59	0.77	ML	0.62	0.14
COMPANY D	0.56	0.88	ML	0.77	0.39
COMPANY E	0.77	0.82	ML	0.69	0.22
COMPANY F	0.88	ML	0.76	0.49	0.14
COMPANY G	0.91	ML	0.69	0.21	0
COMPANY H	0.94	ML	0.53	0.1	0.01

LEGEND	
ML	CURRENT MATURITY LEVEL
	HIGH PULL

Black coloured boxes represent the current average maturity level, while grey coloured boxes represent the high pull. For instance, company B has a stable organisational reliability maturity (level 3) with a pull of 0.95 towards level 4 (sustain). Similarly, companies C, D, and E have stable maturity levels (level 3) but with pulls of 0.77, 0.88, and 0.82 respectively towards level 2 (starter). On the other hand, companies F, G, and H are on maturity levels 2, with pulls of 0.88, 0.91, and 0.94 respectively towards level 1 (silent).

This is also represented by the graph in figure 5.1. The blue curve represents the current maturity level for the organisations and it corresponds with the black boxes on table 5.8. The red curve represents the strong high pull, which corresponds with the grey coloured boxes in table 5.8. The companies are represented on the x axis while the maturity levels are represented by numbers 1 to 5 on the y axis.

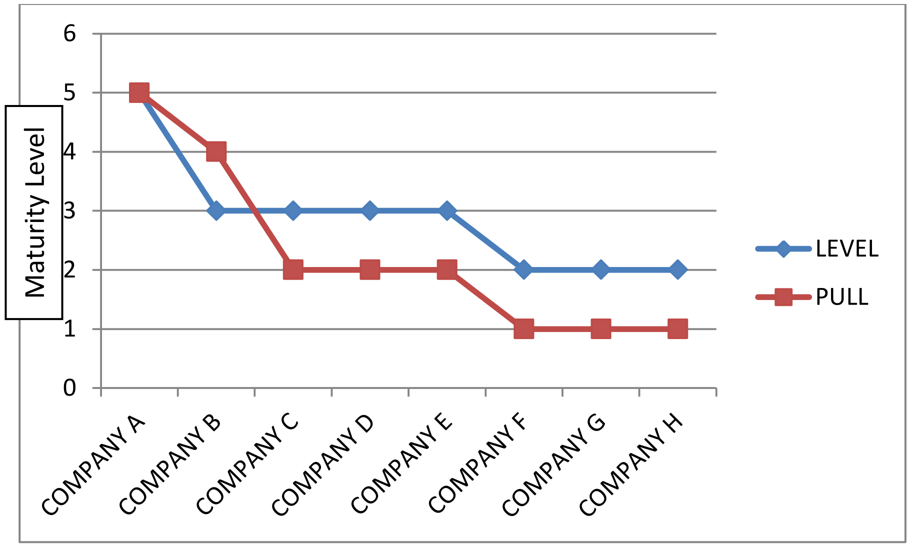


Figure 5.1 – A graph showing a high level comparison of the organisations

The graph makes it easy to visualize the maturity levels of the organisations as well as the pull. It also makes comparisons easy. For instance, it is easier to see that company A is more mature than B, and B is more mature than C. It is also easier to see that companies C, D, and E are on the same maturity level, while F, G, and H are on the same maturity levels.

Table 5.8 and Figure 5.1 consider only average maturity levels of organisations with no consideration to the complexities of individual behaviours in each of the HRO principles. Each of the organisations would continuously monitor their maturity levels as it continues to tend towards the benchmark (company A). The measure of their success or failure would be the extent to which the behaviours deviate from the benchmark behaviours. In addition to benchmarking the organisations at a high level using their average maturity behaviours, the framework could be used to provide detailed benchmarking with a detailed consideration of the behaviours in each of the five HRO principles. This would help the organisations achieve clear understandings and indications of the variance between specific behaviours and the desired standard behaviour. For instance, considering, preoccupation with failure, the detailed review would clearly indicate the variance between the level one behaviour of incidents not being reported for fear of punishment, and the level five behaviour of the management seamlessly working with the frontline staff to actively identify potential hotspots.

Table 5.9 gives a detailed comparison of the organisations with consideration given to each of the HRO principles.

Table 5.9: Detailed comparison of organisational maturity

COMPARING THE MATURITY OF THE ORGANIZATIONS					
ORGANIZATIONS	SILENT	STARTER	STABLE	SUSTAIN	SUMMIT
COMPANY A					
Preoccupation with failure	0.00	4.67	9.83	11.33	74.17
Reluctance to Simplify	0.00	0.00	0.00	8.54	91.46
Sensitivity to operations	0.00	1.82	2.27	9.09	86.82
Commitment to resilience	0.00	0.42	1.46	2.50	95.63
Deference to expertise	0.00	0.00	0.00	3.13	96.88
COMPANY B					
Preoccupation with failure	15.50	17.50	33.67	25.83	7.50
Reluctance to Simplify	6.67	24.79	30.21	22.71	15.63
Sensitivity to operations	5.00	15.68	32.50	27.05	19.77
Commitment to resilience	1.88	8.33	21.25	37.92	30.63
Deference to expertise	35.00	25.31	17.81	15.63	6.25
COMPANY C					
Preoccupation with failure	11.33	22.22	38.44	20.44	7.56
Reluctance to Simplify	16.94	35.83	30.00	16.94	0.28
Sensitivity to operations	5.76	25.15	35.76	24.85	8.48
Commitment to resilience	7.22	17.50	41.94	28.33	5.00
Deference to expertise	40.83	26.25	19.17	12.08	1.67
COMPANY D					
Preoccupation with failure	13.33	26.22	35.78	23.56	1.11
Reluctance to Simplify	21.11	28.89	25.56	18.89	5.56
Sensitivity to operations	10.61	16.97	20.30	32.12	20.00
Commitment to resilience	6.11	26.11	36.11	15.28	16.39
Deference to expertise	27.08	23.75	20.83	17.08	11.25

COMPARING THE MATURITY OF THE ORGANIZATIONS					
COMPANY E					
Preoccupation with failure	47.73	24.80	17.33	7.33	2.80
Reluctance to Simplify	14.17	27.17	32.83	23.00	2.83
Sensitivity to operations	14.36	24.91	28.18	23.82	8.73
Commitment to resilience	0.67	18.17	39.50	28.17	13.50
Deference to expertise	32.25	24.75	22.50	16.50	4.00
COMPANY F					
Preoccupation with failure	40.80	38.93	16.93	3.07	0.27
Reluctance to Simplify	23.83	32.83	28.00	12.83	2.50
Sensitivity to operations	22.55	28.55	24.91	18.36	5.64
Commitment to resilience	17.17	29.00	25.17	22.33	6.33
Deference to expertise	30.00	23.75	21.75	17.75	6.75
COMPANY G					
Preoccupation with failure	46.27	37.47	13.73	2.53	0.00
Reluctance to Simplify	26.83	41.00	28.50	3.67	0.00
Sensitivity to operations	23.09	38.36	31.45	6.91	0.18
Commitment to resilience	25.83	34.67	26.00	13.33	0.17
Deference to expertise	39.50	26.00	22.75	11.25	0.50
COMPANY H					
Preoccupation with failure	49.05	40.67	9.52	0.76	0.00
Reluctance to Simplify	24.76	43.93	27.98	3.33	0.00
Sensitivity to operations	25.06	40.00	26.88	7.14	0.91
Commitment to resilience	39.88	37.14	16.67	5.83	0.48
Deference to expertise	43.39	32.50	22.50	1.61	0.00

Using company A as the benchmark, all other organisations would compare their performances in each of the individual HRO principles against company A's performance. Clearly, none of the organisations come close to the maturity of company A in each of the HRO behaviours. Each of the organisations would however clearly see the variance between their current individual behaviours and the corresponding behaviour in the identified best in class organisation.

The beauty of this framework is its flexibility and ability to be adapted to suit organisational needs. An organisation might wish to perform a detailed benchmarking, and compare the performance of the organisation or business units in each of the HRO principles, against other organisations or business units. Using the data already available in table 5.9, the organisation could generate more tables or graphs to achieve this. Figure 5.2 show a comparison of all the eight organisations in terms of their preoccupation with failure.

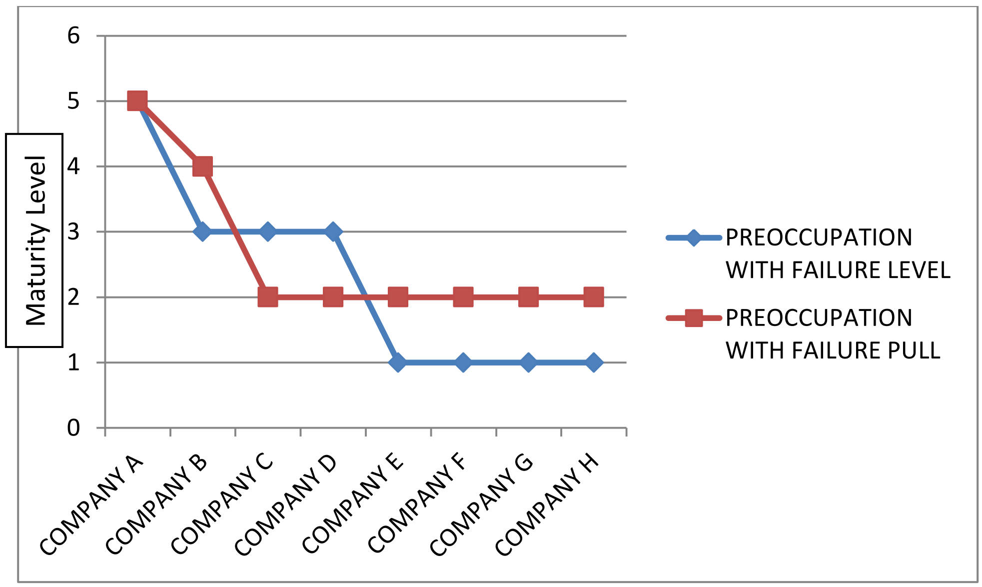


Figure 5.2 – A graph showing a comparison of the organisations in terms of their preoccupation with failure.

As in table 5.1, the blue curve represents the current maturity levels of the organisations, this time with respect to their preoccupation with failure. The red curve represents the high pull for each with respect to their preoccupation with failure. Again it is easy to visualize the similarities and differences between the organisations. All the graphs included in this section would follow the same format and legend. The maturity levels would be represented on the y – axes, while the organisations would be represented on the x – axes. The red curve will represent the pull, while the blue curve will represent the maturity level for that organisation.

Figure 5.3 is a graphical representation of the comparison between the organisations with respect to their reluctance to simplify.

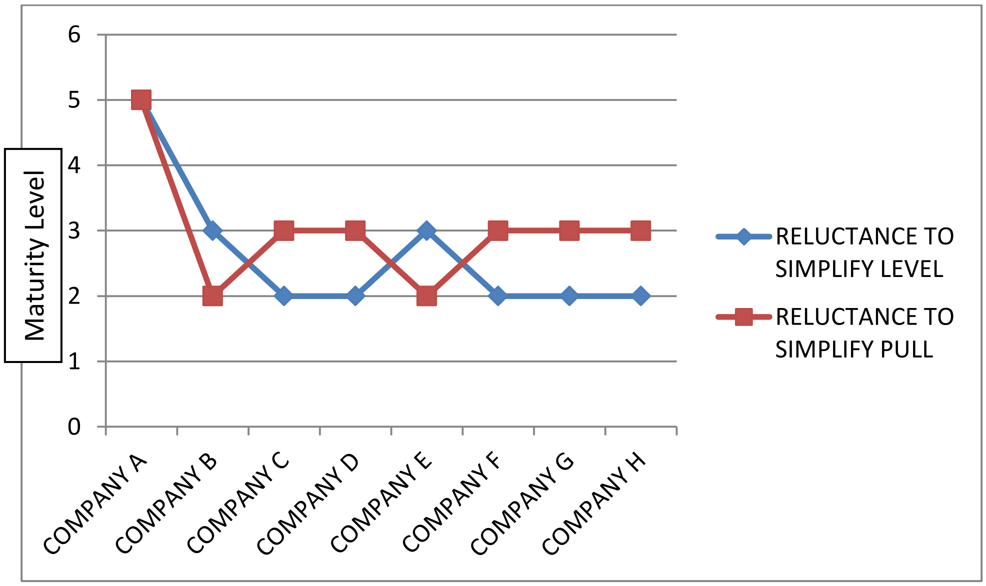


Figure 5.3 – A graph showing a comparison of the organisations in terms of their reluctance to simplify.

From the graph, company C, D, F, G, and H on maturity level 2 are more mature than B and E on maturity level 3 with respect to their reluctance to simplify. However, while B and E are showing signs of improving towards level 2, the rest are showing signs of retrogressing towards level 3. The graphs could therefore not only be used for benchmarking, but also for predicting the potential for improvement or retrogression.

Figure 5.4, figure 5.5, and figure 5.6 show the comparison of the organisations with respect to their sensitivity to operations, commitment to resilience, and deference to expertise respectively. They all follow the same format and legends as in the last three figures in this section.

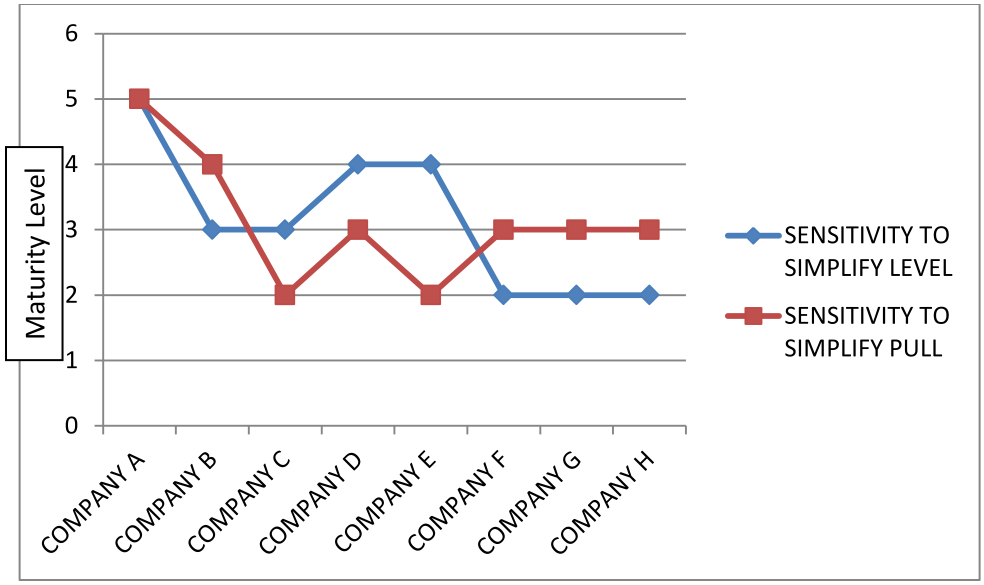


Figure 5.4 – A graph showing a comparison of the organisations in terms of their sensitivity to operations.

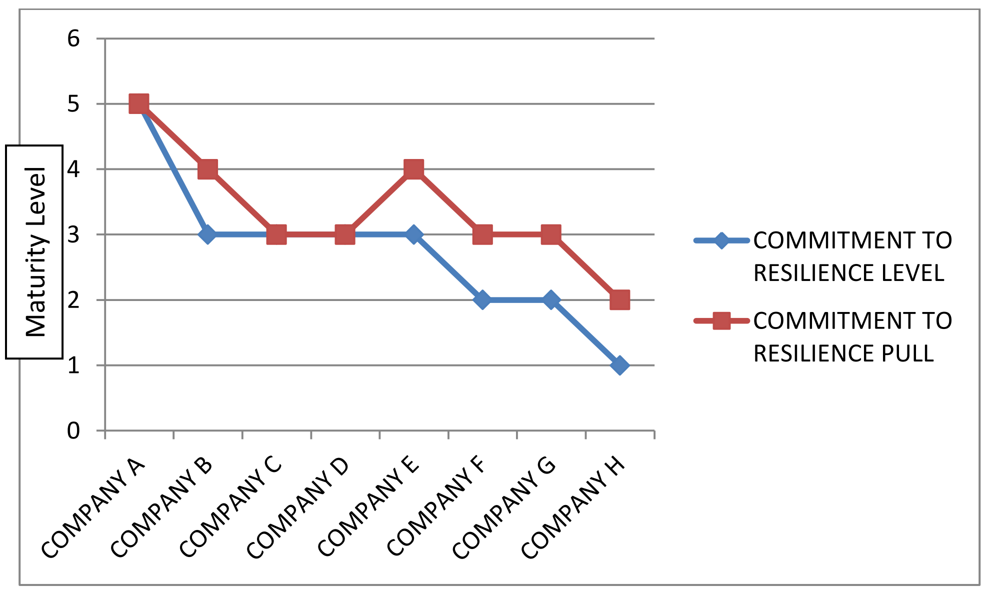


Figure 5.5 – A graph showing a comparison of the organisations in terms of their commitment to resilience.

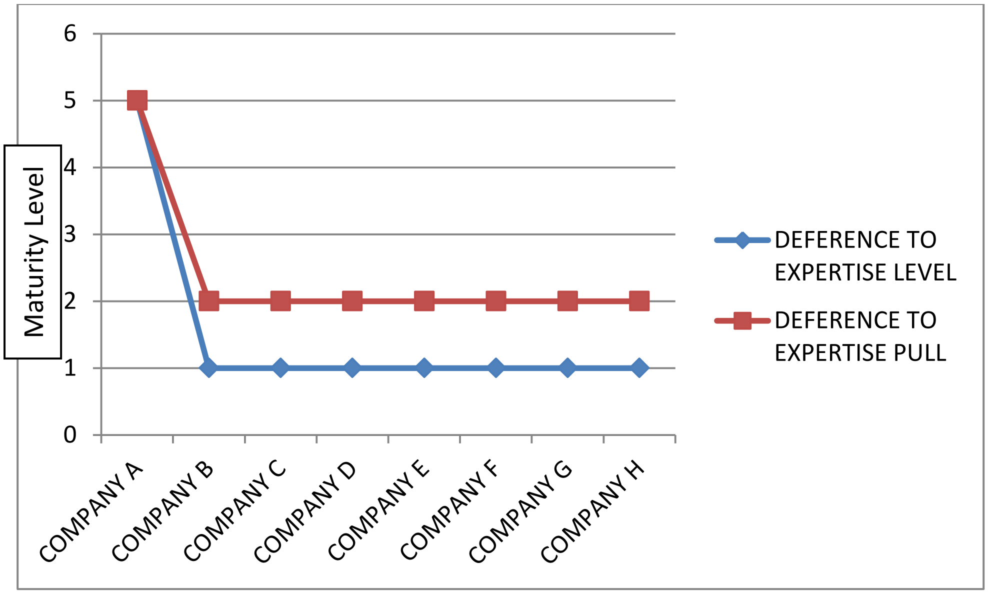


Figure 5.6 – A graph showing a comparison of the organisations in terms of their deference to expertise.

5.6.2. Benchmarking against peers

Companies A and B are both international oil and gas organisations and therefore could be considered as peers. Companies C and D are both oil and gas companies formed within the same time frame, operating within the same region, with similar operational challenges, and therefore could be considered as peers. Companies E and F are considered peers to the extent that they are operating within the same industry and could be benchmarked as such. In reality however, while company F is a relatively new and localised organisation, company E is a relatively much older organisation, and a subsidiary of an international organisation with globalized brands. Both would however be treated as peers for the sake of this research. Companies G and H would be given the same considerations as E and F. They would also be considered peers as both are operating in the same industry.

Table 5.10 shows the comparison of companies A and B. Company B obviously lag company A widely in all the HRO behaviours. Company B at maturity level 3 is improving towards level 2 and would need to implement a lot of improvement initiatives to reach the best in class standard of its peer, company A.

Table 5.10: Comparing companies A and B

COMPANY B (OIL &GAS)							
Level	Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise	**Average Score**	Pull
5	7.50	15.63	19.77	30.63	6.25	**15.95**	0.59
4	25.83	22.71	27.05	37.92	15.63	**25.83**	0.95
3	33.67	30.21	32.50	21.25	17.81	**27.09**	0.00
2	17.50	24.79	15.68	8.33	25.31	**18.32**	0.68
1	15.50	6.67	5.00	1.88	35.00	**12.81**	0.47
COMPANY A (OIL &GAS)							
Level	Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise	**Average Score**	Pull
5	74.17	91.46	86.82	95.63	96.88	**88.99**	0.00
4	11.33	8.54	9.09	2.50	3.13	**6.92**	0.08
3	9.83	0.00	2.27	1.46	0.00	**2.71**	0.03
2	4.67	0.00	1.82	0.42	0.00	**1.38**	0.02
1	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00

A high level comparison of companies C and D shows both organisations to be close on the average high level behaviours (table 5.11). They are both on the same maturity level 3 with higher pulls towards level 2. There are also fairly being pulled strongly towards level 4 at 0.62 and 0.77 respectively.

Table 5.11: High level comparison of companies C and D

COMPARING THE MATURITY OF THE ORGANIZATIONS					
ORGANIZATIONS	**SILENT**	**STARTER**	**STABLE**	**SUSTAIN**	**SUMMIT**
COMPANY C	0.59	0.77	ML	0.62	0.14
COMPANY D	0.56	0.88	ML	0.77	0.39

A closer look at the detailed comparison (fig 5.11) would however highlight the key differences between both organisations. Both organisations exhibit similar behaviours in preoccupation with failure, reluctance to simplify, and deference to expertise. In their sensitivity to operations, company C is at maturity level 3 with fairly even pulls towards levels 2 and 4. The pull towards level 2 is slightly higher thus the organisation is said to be pulling towards level 2. Company D on the other hand is at level 4 with fairly even pulls towards levels 3 and 5. The pull towards level 3 is slightly higher than the pull towards level 5, thus the organisation is said to be pulling towards level 3. Company D is therefore considered to have performed better than company C in their sensitivity to operations.

Table 5.12: Detailed comparison of companies C and D

COMPARING THE MATURITY OF THE ORGANIZATIONS							
ORGANIZATIONS	SILENT	STARTER	STABLE	SUSTAIN	SUMMIT		
COMPANY C							
Preoccupation with failure	11.33	22.22	38.44	20.44	7.56	LEGEND	
Reluctance to Simplify	16.94	35.83	30.00	16.94	0.28		
Sensitivity to operations	5.76	25.15	35.76	24.85	8.48	ML	CURRENT MATURITY LEVEL
Commitment to resilience	7.22	17.50	41.94	28.33	5.00		HIGH PULL
Deference to expertise	40.83	26.25	19.17	12.08	1.67		
COMPANY D							
Preoccupation with failure	13.33	26.22	35.78	23.56	1.11	LEGEND	
Reluctance to Simplify	21.11	28.89	25.56	18.89	5.56		
Sensitivity to operations	10.61	16.97	20.30	32.12	20.00	ML	CURRENT MATURITY LEVEL
Commitment to resilience	6.11	26.11	36.11	15.28	16.39		HIGH PULL
Deference to expertise	27.08	23.75	20.83	17.08	11.25		

Both organisations are on the same maturity level 3 in their commitment to resilience. Company C is however pulled strongly towards level 4 while company D is pulled towards maturity level 2. Company C is therefore considered to have performed better than company D in their commitment to resilience.

Similarly, a high level comparison of companies E and F (table 5.13) indicates company E to be performing better than company F. Whereas company is E at maturity level 3 with a strong pull of 0.82 towards level 2, company F is at maturity level 2 with a strong pull of 0.88 towards level 1.

Table 5.13: High level comparison of companies E and F

COMPARING THE MATURITY OF THE ORGANIZATIONS					
ORGANIZATIONS	SILENT	STARTER	STABLE	SUSTAIN	SUMMIT
COMPANY E	0.77	0.82	ML	0.69	0.22
COMPANY F	0.88	ML	0.76	0.49	0.14

A closer look at the detailed comparison (table 5.14) would highlight the key differences and similarities between the behaviours of companies E and F in each of the five HRO principles. The performances are similar in their preoccupation with failure and deference to expertise. Considering their reluctance to simplify, company E is at maturity level 3 with a strong pull towards maturity level 2. It is also fairly pulled towards level 4. Company F on the other hand is at maturity level 2 with a strong pull towards level 3. It is also fairly pulled towards level 1. Company E is therefore considered to have performed better than company F in their reluctance to simplify.

Table 5.14: Detailed comparison of companies E and F

COMPARING THE MATURITY OF THE ORGANIZATIONS							
COMPANY E						**LEGEND**	
Preoccupation with failure	47.73	24.80	17.33	7.33	2.80		
Reluctance to Simplify	14.17	27.17	32.83	23.00	2.83	ML	CURRENT MATURITY LEVEL
Sensitivity to operations	14.36	24.91	28.18	23.82	8.73		HIGH PULL
Commitment to resilience	0.67	18.17	39.50	28.17	13.50		
Deference to expertise	32.25	24.75	22.50	16.50	4.00		
COMPANY F							
Preoccupation with failure	40.80	38.93	16.93	3.07	0.27	**LEGEND**	
Reluctance to Simplify	23.83	32.83	28.00	12.83	2.50		
Sensitivity to operations	22.55	28.55	24.91	18.36	5.64	ML	CURRENT MATURITY LEVEL
Commitment to resilience	17.17	29.00	25.17	22.33	6.33		HIGH PULL
Deference to expertise	30.00	23.75	21.75	17.75	6.75		

Considering their sensitivity to operations, company E is at maturity level 3 with a strong pull towards level 2. It is also pulled fairly towards level 4. On the other hand, company F is at a maturity level 2 with a strong pull towards maturity level 3. It is however also being pulled fairly towards level 1. Company E is therefore said to have performed better that company F in their sensitivity to operations. Finally, considering their commitment to resilience, company E is at maturity level 3 with a strong pull towards level 4, while company F is at maturity level 2 with a strong pull towards level 3. Again, company E is said to have performed better than company F.

Finally, a high level comparison of companies G and H (table 5.15) indicates that both companies exhibit similar behaviours. Both competitors are at maturity levels 2 with high pulls towards level 1 and low pulls towards level 3.

Table 5.15: High level comparison of companies G and H

COMPARING THE MATURITY OF THE ORGANIZATIONS						**LEGEND**	
ORGANIZATIONS	**SILENT**	**STARTER**	**STABLE**	**SUSTAIN**	**SUMMIT**		
COMPANY G	0.91	ML	0.69	0.21	0	ML	CURRENT MATURITY LEVEL
COMPANY H	0.94	ML	0.53	0.1	0.01		HIGH PULL

Company G however has a less high pull (0.91) towards maturity level 1 than company H (0.94), and a stronger low pull (0.69) towards maturity level 3 than company H. Company G is therefore considered more mature than Company H. Table 5.16 shows the detailed comparison of the behaviours of companies G and H in terms of the individual HRO principles.

Table 5.16: Detailed comparison of companies G and H

COMPARING THE MATURITY OF THE ORGANIZATIONS					
ORGANIZATIONS	SILENT	STARTER	STABLE	SUSTAIN	SUMMIT
COMPANY G					
Preoccupation with failure	46.27	37.47	13.73	2.53	0.00
Reluctance to Simplify	26.83	41.00	28.50	3.67	0.00
Sensitivity to operations	23.09	38.36	31.45	6.91	0.18
Commitment to resilience	25.83	34.67	26.00	13.33	0.17
Deference to expertise	39.50	26.00	22.75	11.25	0.50
COMPANY H					
Preoccupation with failure	49.05	40.67	9.52	0.76	0.00
Reluctance to Simplify	24.76	43.93	27.98	3.33	0.00
Sensitivity to operations	25.06	40.00	26.88	7.14	0.91
Commitment to resilience	39.88	37.14	16.67	5.83	0.48
Deference to expertise	43.39	32.50	22.50	1.61	0.00

LEGEND	
ML	CURRENT MATURITY LEVEL
	HIGH PULL

Both organisations appear to have very similar behaviours in all HRO principles except commitment to resilience where company G is at maturity level 2 and a high pull towards maturity level 3. Company H on the other hand is at maturity level 1 tending towards maturity level 2. In order to dig further into the individual difference between both organisations in the four HRO principles in which their behaviours appear to be very similar, a simple pull calculation would be required as demonstrated in section 5.3. In addition to benchmarking against peers and against best in class, this framework could be adopted by organisations to benchmark internally against its various departments or business units. The process would be the same as described in the preceding sections. The key thing would be to obtain data that is accurate and robust enough to reflect the true organisational realities.

The next section shall describe how this framework could be used in organisational learning and performance improvement.

5.7 Applying the Framework for Organisational Reliability Maturity (FORM) in performance improvement.

The route organisations would choose to improve their organisational reliability would be determined by the amount of resources they are willing to commit. For best results, a wholesome implementation is suggested. The improvement actions would normally be in a stepwise manner, in which case, the organisations would take incremental actions to improve their maturity one level at a time. This could potentially pose some challenges in cases where the pull towards a higher maturity level is very high. A pull of 0.9 from level 1 towards level 2 indicates that the organisation already exhibits a lot of level 2 behaviours. A smarter decision in this case would therefore be to begin to implement level 3 behaviours instead of committing resources on level 2 behaviours. For simplicity, this research recommends a pull of 0.7 as the level gate, beyond which the organisation should begin to implement behaviours of the maturity level above. In the example above, the organisation would begin to implement behaviours of level 3 instead of level 2. Where the organisation has reached a maturity of level 5, it would be expected to sustain the maturity by continuously assessing its behaviours against the level 5 behaviours.

Where an organisation is unable to the commit resources required to implement all 5 HRO principles at the same time, it could chose to commit more resources to its weakest principle(s) as a means of boosting the average maturity level. This route is however a bit tricky and must be used in conjunction with an organisational risk analysis. This research assumes an equal weighting for all the 5 HRO principles. An organisational risk analysis might recommend a different weighting for the principles due to the prevalent risk factors. *Company B* might for instance, consider *preoccupation with failure* as most important, and could chose to commit resources to it, rather than in *deference to expertise* where it scored the least. Company H, a service oriented organisation, on the other hand might choose to give a higher weighting to sensitivity to operations. A future research could identify a standardized weighting process for organisations in similar industries.

The Organisational Reliability Maturity Model (ORM^2) must be used in conjunction with the Framework for Organisational Reliability Maturity (FORM) to propose organisational improvement behaviours. Having attained best in class, company A might be tempted to relax its efforts. This could prove a costly mistake as retrogression could occur within a short period. What the company had spent years to build could be lost within a few months of laxity. For such organisation, it must continue to encourage the behaviours that made it best in class, and at the same time must continuously evaluate itself against its benchmark to enhance the sustainability of the best in class behaviours. Furthermore, it must realize that it did not score 100% in any of the HRO principles. This means there is room for improvement. A score of 74% in preoccupation with failure means that there is a 26% room for improvement, in addition to the sustainability initiatives it would adopt. Similarly, there is 9% room for improvement in reluctance to simplify; 13% room for improvement in sensitivity to operations; 4% room for improvement in commitment to resilience, and a 3% room for improvement in deference to expertise. Table 5.17 shows the FORM table for company A.

Table 5.17: Framework for Organisational Reliability Framework (FORM) for Company A – Applying ORM^2

COMPANY A (OIL &GAS)							
Level	Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise	**Average Score**	Pull
5	74.17	91.46	86.82	95.63	96.88	**88.99**	0.00
4	11.33	8.54	9.09	2.50	3.13	**6.92**	0.08
3	9.83	0.00	2.27	1.46	0.00	**2.71**	0.03
2	4.67	0.00	1.82	0.42	0.00	**1.38**	0.02
1	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00

Table 5.18 shows the FORM table for company B. The organisation is at maturity level 3 and with a high pull of 0.95 towards maturity level 4. The organisation is therefore either improving towards level 4 or has retrogressed from level 4 based on the earlier baseline data that is not available for the purpose of this research. Whether improving or retrogressing, the organisation clearly needs to learn from the best in class organisations and develop initiatives aimed at organisational improvement. To achieve this, it must identify the individual reliability behaviours it must focus improvement initiatives on.

Table 5.18: Framework for Organisational Reliability Framework (FORM) for Company B – Applying ORM^2

COMPANY B (OIL &GAS)							
Level	Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise	**Average Score**	Pull
5	7.50	15.63	19.77	30.63	6.25	**15.95**	0.59
4	25.83	22.71	27.05	37.92	15.63	**25.83**	0.95
3	33.67	30.21	32.50	21.25	17.81	**27.09**	0.00
2	17.50	24.79	15.68	8.33	25.31	**18.32**	0.68
1	15.50	6.67	5.00	1.88	35.00	**12.81**	0.47

Its worst performance was in deference to expertise, where it performed at maturity level 1. From ORM^2, level 1 behaviour in deference to expertise includes unavailability of expertise within the organisation, people generally not aware of who has the most expertise for specific emergencies and a strong reliance on hierarchical authority during emergencies instead of expertise. Applying the pull calculation $P = 1 - (R - Ri)/R$ to deference to expertise, where R is 35 and Ri is 25.31, the high pull would be 0.72 towards level 2. There is also a low pull of 0.51 towards level 3. This suggests that the organisation may have already started exhibiting some level 2 and 3 behaviours. Using the heuristic method developed earlier in section 5.7, where a stage gate of 0.7 was adopted for improvement actions, company B would therefore develop organisation improvement actions for level 3. A pull of 0.51 is also relatively high and the organisation might begin to introduce level 4 behaviours while auditing only for level 3 at this point.

The high number of respondents that chose level 3 suggests that there had been some standardisation efforts that were not sustained, or that the organisation is currently implementing some standardization initiatives. The audits must be to ensure all the standardization required for level 3 are in place and being implemented by the organisation. At level 4 in deference to expertise, there is expertise available for most emergencies and people generally know who the experts are or how to access the expertise during emergencies. It also means that the hierarchical leader under normal operation would normally yield authority to the expert during emergency, and that the expert would normally yield back authority to the hierarchical leader as soon as the emergency is over and normal operation resumes. The organisation would therefore initiate improvement processes to enhance these level 4 behaviours to improve its organisational reliability maturity.

The organisation is at maturity level 3 in its reluctance to simplify. Applying the pull calculation to this principle, the high pull will be 0.82 towards level 2. There is a low pull of 0.75 towards level 4. Based on the heuristic method developed earlier, the improvement actions should be level 5 improvement actions. However, the high pull of 0.82 is strongly pulling the organisation down towards level 2, and as such, level 5 improvement actions may be asking too much. The organisation in this instance would therefore develop or reemphasize level 4 behaviours for its improvement initiatives. Level 2 behaviours in reluctance to simplify include actions that discourage scepticism and challenge of processes and norms. Level 3 behaviours involved standardised processes and procedures to encourage scepticism and challenge of processes and procedures. Implementation is however often delayed by layers of bureaucracies and bottlenecks. Level 4 behaviours to be implemented by the organisation would include initiatives to ensure the opinions of skeptics and people who think outside the box are respected, and given its due merit.

The organisation is also at maturity level 3 in both preoccupation with failure and sensitivity to operations with high pulls towards level 4 on both. The organisation would therefore develop improvement actions to achieve level 4 behaviours. Being on level 3 means that there are standardized process. Level 4 behaviours for preoccupation with failure include near misses and incidents are being reported, root causes are identified for failures and near misses, and people are not blamed for causing incidents. There is clear and open communication among team members, and between team members and management, worst case scenarios are considered during all plans, and all lessons learned are itemized and documented for each incident and near miss identified. Level 4 behaviours on sensitivity to operations include conducting regular meetings with clearly defined terms of reference, leaders getting involved in day to day front line activities, and front line staff giving first hand reports for day to day activities. It also involves people generally willing to get involved in jobs outside their core competencies, opportunities being made available for people to get involved in jobs outside their core competencies, feedbacks given and received with little prompts, and leaders continuously monitoring workloads and optimizing resources in line with those workloads.

Finally, company B is on maturity level 4 in its commitment to resilience with a high pull towards level 5. Improvement initiatives would clearly be geared towards level 5 behaviours. At level 4, the leaders and staff are already working together to identify learning and development gaps and close them. Competence assessment is already being done willingly at specified times, emergency drills are no longer regarded as necessary evils, but useful ways to potentially save lives and protect the environment. Processes for level 5 would therefore be developed such that competence and skills development becomes a proactive process, emergency response and contingency plans become robust and implementation becomes a shared responsibility among all staff and management. People would also generally have more than enough skills for their jobs and for responding to emergencies. Finally, everyone would trust one another and rely on one another during emergencies.

The same process used above could be used for all the other organisations studied. For instance, considering *Company G* and *H,* both organisations are at maturity level 2 with high pulls towards level 1. From ORM^2, and considering *preoccupation with failure*, both organisations do not report near misses or incidents, neither is there a process in place to manage incidents. They consider failure to be the result of someone's error and there are punishments for people found to cause a failure. The managements are considered as being difficult to approach. Both organisations pull strongly towards level 2 at 0.81 and 0.83 respectively, meaning that a large percentage may have already started to report some incidents or near misses, but there is no defined process to manage incidents, neither is there a formal communication channel with management.

Table 5.19: Framework for Organisational Reliability Framework (FORM) for Company G and Company H – Applying ORM[2]

COMPANY H (RESTAURANT CHAIN)							
Level	Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise	**Average Score**	Pull
5	0.00	0.00	0.91	0.48	0.00	**0.28**	0.01
4	0.76	3.33	7.14	5.83	1.61	**3.74**	0.10
3	9.52	27.98	26.88	16.67	22.50	**20.71**	0.53
2	40.67	43.93	40.00	37.14	32.50	**38.85**	0.00
1	49.05	24.76	25.06	39.88	43.39	**36.43**	0.94
COMPANY G (RESTAURANT CHAIN)							
Level	Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise	**Average Score**	Pull
5	0.00	0.00	0.18	0.17	0.50	**0.17**	0.00
4	2.53	3.67	6.91	13.33	11.25	**7.54**	0.21
3	13.73	28.50	31.45	26.00	22.75	**24.49**	0.69
2	37.47	41.00	38.36	34.67	26.00	**35.50**	0.00
1	46.27	26.83	23.09	25.83	39.50	**32.30**	0.91

A smart recommendation would therefore be for the organisations to begin to implement level 3 behaviours. Such behaviour would include developing and implementing a formalised incident management process, communication process, and rewards process. A robust incident management process would include a feedback process to improve future process design, modify existing process or implement cultural change.

Both organisations are also on maturity level 2 in their *reluctance to simplify* with high pulls of 0.70 and 0.64 respectively. Again, the smart recommendation would be to implement level 3 behaviours that aim at process standardisation. In both organisations, there are strong pulls towards level 1, which suggests that gains made to attain level 2 or 3 could easily be eroded and the organisations could easily slide down to level 1. Both organisations follow the same pattern in their *sensitivity to operations* as in *their reluctance to simplify*. The smart recommendation would also be to adopt level 3 behaviours which primarily centre on standardisation of the processes. Such behaviours would include meetings at regular intervals with clearly defined terms of reference, clearly defined work reporting process, percentage of work outside employees' key competences, formalised feedback process, and formalised work load management process. When the organisation has gotten used to the straight jacket formalised processes, they could then begin to implement behaviours in level 4 that will help the people to perform their work mindfully without coercion.

While *Company H* is at level 1 in *commitment to resilience* with a high pull of 0.93 towards level 2, *Company G* is at level 2 with a high pull of 0.75 towards level 3. *Company H* would therefore be smart enough to begin to encourage level 3 behaviours, while *Company G* would encourage level 4 behaviours. Level 3 behaviours in *commitment to resilience* include design and implementation of formalised trainings and competence assessment process. Competence and skills assessment is done at specific times across the organisation. It also includes formalised emergency response and contingency plans, where people are mandated to learn and adopt. People however still regard the drills and emergency response plans as necessary burden to please the employer. At level 4, the people begin to get involved mindfully, and would often get together with the leaders to identify training and development gaps and mutually agree on plans to close the gaps. Competence and skills assessment is an ongoing and continuous process in level 4, and people actively give and receive feedback at predetermined times. The people at this point begin to see the potentials of drills and emergency response plans to save lives, preserve assets, and preserve the environment.

Both organisations are at level 1 in their *deference to expertise* and exhibits similar behaviour in the principle. While *Company H* has a high pull of 0.75 towards level 2, *Company G* has a high pull of 0.68 towards level 2. *Company H* is additionally being pulled strongly at 0.52 towards level 3, while Company *G* is additionally being pulled strongly at 0.58 towards level 3. The smart choice would therefore be to begin to encourage level 4 behaviours in both organisations. At level 4, the expected *deference to expertise* behaviour includes sacrificing hierarchy on the altar of expertise. The most senior would normally *yield* responsibility to the most experienced people during an emergency. The emphasis is on *yield*, as the process is intentional and not out of coercion. The experienced people accept the responsibility professionally and *yield* the responsibility back after the emergency. In level, 4, expertise for all emergencies is readily available.

Companies C and D are peers within the oil and gas industry. Catastrophic failures could result from behaviours that are not mindful in any of the five HRO. The failure to report a leak (not preoccupied with failure); or casually categorising it as a “minor” leak that does not require urgent attention (over simplification); or disregarding the potential interrelationship between that “minor” leak with the other processes (not sensitive to operations) could result in the “minor” leak escalating into a full blown catastrophe. The “minor” leak could potentially result in an explosion and fire, multiple fatalities and asset destruction, and environmental damage. This catastrophe could result to a full blown disaster if the organisation is unable to manage the emergency response (commitment to resilience), or the people with the expertise are not given full authority to manage the emergency. Chapters two and three described numerous cases where this industry witness catastrophes resulting from one or more lapses in the HRO behaviours. The organisations must therefore develop improvement initiatives to improve maturity.

Table 5.20 shows the FORM table for companies C and D. Both are at maturity level 3 with high pulls down towards maturity level 2. Looking at the big picture, both organisations are being pulled strongly down towards level 2 and would therefore initiate improvement actions that ensure they not only sustain level 3, but begin to improve towards maturity level 4.

Table 5.20: Framework for Organisational Reliability Framework (FORM) for Company C and Company D – Applying ORM^2

COMPANY D (OIL &GAS)							
Level	Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise	**Average Score**	Pull
5	1.11	5.56	20.00	16.39	11.25	**10.86**	0.39
4	23.56	18.89	32.12	15.28	17.08	**21.39**	0.77
3	35.78	25.56	20.30	36.11	20.83	**27.72**	0.00
2	26.22	28.89	16.97	26.11	23.75	**24.39**	0.88
1	13.33	21.11	10.61	6.11	27.08	**15.65**	0.56
COMPANY C (OIL &GAS))							
Level	Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise	**Average Score**	Pull
5	7.56	0.28	8.48	5.00	1.67	**4.60**	0.14
4	20.44	16.94	24.85	28.33	12.08	**20.53**	0.62
3	38.44	30.00	35.76	41.94	19.17	**33.06**	0.00
2	22.22	35.83	25.15	17.50	26.25	**25.39**	0.77
1	11.33	16.94	5.76	7.22	40.83	**16.42**	0.50

Applying the same process applied to companies B, G and H, companies C and D must implement level 4 behaviours while ensuring that they sustain level 3 behaviours in their preoccupation with failure. As done in companies B, G, and H, the behaviours would be developed using the organisational reliability maturity model (ORM^2). Considering their reluctance to simplify, both companies C and D are on maturity level 2 with high pulls at maturity level 3. Applying the pull calculation, there is also a pull of 0.73 towards level 1 in company D and pulls of 0.47 towards levels 1 and level 4 in company C. This indicates that both organisations have more potential to improve towards level 3 from maturity level 2.

With a further pull of 0.73 towards level 1, company D could potentially slide down towards level 1. Again improvement actions would be developed from ORM^2 not only to sustain level 2 maturity in their reluctance to simplify, but additionally to improve to level 3. Considering sensitivity to operations, company D is at maturity level 4 with almost equal pulls towards levels 3 and 5. The organisation could potentially improve towards level 5 or slide down towards level 3 given current behaviours. A wise decision would be to sustain level 4 behaviours while implementing policies that would help them develop level 5 behaviours.

Company C on the other hand is at maturity level 3 with almost equal pull towards levels 2 and 4. Again, the organisation would be wise to use ORM^2 to develop level 3 sustainability initiatives to ensure it does not retrogress to maturity level 2, while developing initiatives to improve towards level 4. Next level target behaviours would therefore be level 4 behaviours. Whereas company C is at level 3 with a high pull towards level 4 in commitment to resilience, company D is at level 3 with a high pull towards level 2. This means that while company D could potentially improve, company C could potentially retrogress. Company C would therefore focus more on sustainability actions while company D would focus more on next level improvement actions. Both organisations are on level 1 in their deference to expertise and must therefore implement similar initiatives recommended for companies D, G, and H to improve their behaviours on deference to expertise.

Finally, applying ORM^2 to companies E and F would be similar in large parts to companies H and H. One of the key differences is in the overall performance. While company F, like G and H, is on maturity level 2 with a high pull towards level 1, company E is on maturity level 3 with a high pull towards level 2, and a further pull of 0.77 towards level 1.

Table 5.21: Framework for Organisational Reliability Framework (FORM) for Company E and Company F – Applying ORM^2

COMPANY F (BEVERAGE MANUFACTURING)							
Level	Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise	**Average Score**	Pull
5	0.27	2.50	5.64	6.33	6.75	**4.30**	0.14
4	3.07	12.83	18.36	22.33	17.75	**14.87**	0.49
3	16.93	28.00	24.91	25.17	21.75	**23.35**	0.76
2	38.93	32.83	28.55	29.00	23.75	**30.61**	0.00
1	40.80	23.83	22.55	17.17	30.00	**26.87**	0.88
COMPANY E (BEVERAGE MANUFACTURING)							
Level	Preoccupation with Failure	Reluctance to Simplify	Sensitivity to Operations	Commitment to Resilience	Deference to Expertise	**Average Score**	Pull
5	2.80	2.83	8.73	13.50	4.00	**6.37**	0.22
4	7.33	23.00	23.82	28.17	16.50	**19.76**	0.69
3	17.33	32.83	28.18	39.50	24.75	**28.52**	0.00
2	24.80	27.17	24.91	18.17	22.50	**23.51**	0.82
1	47.73	14.17	14.36	0.67	32.25	**21.84**	0.77

Both organisations would be smart to implement level 3 behaviours: company E for sustainability reasons and company F for organisational improvement reasons. How organisations use the framework for organisational reliability maturity (FORM) and the organisational reliability maturity model to develop and enhance learning forms the next section.

5.8 Applying the Framework for Organisational Reliability Maturity (FORM) and ORM^2 in organisational learning.

Organisational learning in this instance could be learning either learning from oneself, learning from others, or a combination of both. When organisations develop their baseline measurements, they document them and use them as benchmarks to compare future organisational reliability performances. As they continue to perform improvement actions to improve and sustain organisational maturity, they accumulate experience which becomes embedded within the organisation. These experiences become the repository for organisational learning.

Using FORM and ORM^2 to develop improvement and sustainability actions, organisations develop and reinforce explicit and tacit knowledge. Explicit knowledge includes the processes, procedures, standards, and instructions that the organisations would develop and enforce at maturity level 3. Every member of the organisations would be expected to understand and work with this well documented explicit knowledge. Tacit knowledge on the other hand is not easily documented. They are the proactive and generative behaviours of level 4 and level 5 respectively that are learned through experience over time. It is mostly achieved through on-the-job learning, coaching, and continuous practice. For instance, the no-blame behaviours of maturity level 5 in the preoccupation with failure HRO principle, or the open and proactive collaborations and feedback between the employees and management personnel in the sensitivity to operations HRO principle are both tacit knowledge that can only be developed through experience and series of continuous improvement learnings.

Benchmarking is another useful means of organisational learning. Organisations are able to observe the practices of other organisations and learn from their successes and their failures. For instance, when a disaster occurs, organisations could identify the root causes of these disasters and correlate with their own organisation. Relationships between the disasters and their organisational reliability maturity would form more input towards their organisational improvement and learning.

It is one thing to create knowledge, and another to retain the knowledge. An organisation could easily jump from organisational learning to organisational forgetting through a succession of unchecked behaviours. Knowledge retention is concerned with the organisational reliability behaviours that have become embedded within the organisation through implementation of the various organisational maturity improvement actions.

Knowledge retention is achieved through the use of people as repositories. As people gain experience and improve their organisational reliability behaviours, they help transfer the knowledge through various organisational learning and development initiatives. Repositories are useful tools to increase retention. The use of people as repositories is one of the worst methods of knowledge retention. This increases the vulnerability of organisations to lose the information due to attrition, layoffs, and retirements. Furthermore, having become the repositories for the organisations reliability improvement knowledge, some people could hold onto the knowledge either to gain more relevance, or are simply not capable of knowledge transfer. As the attrition rate increases, the people with key knowledge continue to leave the organisation and the organisation could easily begin to retrogress in their maturity behaviours.

Other forms of repositories include communication tools such as computers, tapes, CDs, and other electronic memory devices. The processes and standards set by the organisation is a very useful repository of knowledge.

At maturity level 3, organisations develop, implement and enforce processes and standards to guide their reliability behaviours. At levels 4 and 5, these organisations become proactive and generative, no longer relying on enforcing the processes and standards, but with the people adopting the processes and standards as parts of their everyday work life. At this stage, personnel changes become insignificant as new employees would only have to work to fit into an existing process. Others repositories that could be adopted together with ORM^2 and FORM include organisational routines, networks, learning agendas, and transactive memory or group think. Different organisations would develop processes to aid knowledge retention and knowledge transfer.

Finally, the ORM^2 and FORM can be utilized to enhance individual learning, group learning, organisational learning, and inter-organisational learning. Individual learning in this instance refers to the learning by the various people within the organisation that would implement the improvement and sustainability initiatives. Group learning refers to individual team and sub divisions when there is an internal benchmarking. Organisational learning refers to the progressive learning by the individual organisation either when it learns from itself or from others. Inter-organisational learning refers to industry wide learning or cross industry learning. For instance, the Piper Alpha incident led to a lot of process safety learnings that resulted in the promulgation of Offshore Installations (Safety case) Regulations of 1992 (UK Statutory Instruments, 1992). This is now a requirement for oil and gas industries all over the world. A benchmark against a best in class organisational reliability behaviour could be utilized by different organisations within the industry and beyond to develop their own processes and thereby enhance organisational learning.

5.9 Chapter Summary

The research started with the aim of applying the HRO theory to improve the maturity of organisations. It asked two questions:

- To what extent can the mindfulness of organisations be measured?
- Can these measurements help diverse organisations become more mature?

Chapter five has answered both questions. First, it developed the organisational reliability maturity model (ORM^2) that identified specific reliability enhancing behaviours in organisations for each of the five high reliability organisation principles and mapped them into five levels of maturity. The levels were named *silent, starter, stable, sustain, and summit*, with *silent* being the lowest maturity level (level 1) and *summit* being the highest maturity level (level 5). This provided baseline measurement for organisations to assess their current statuses in terms of organisational reliability maturity. It also initiated the answer to the first question: "… can the mindfulness of organisations be measured?"

Furthermore, the chapter introduced the framework for organisational reliability maturity, a framework to track the responsiveness of the organisations with respect to each of the five HRO principles.

To fully answer the first question, the research realised that the framework must be able to perform a health check that assesses the current maturity level of organisations. Secondly, the framework must have the ability to use the current organisational reliability behaviours to predict the future direction the organisation could potentially go. Finally, the framework must have the ability to benchmark organisations against desired maturity standards, either internally or externally.

The chapter developed the pull calculation $P = 1 - (R - Ri)/R$, where P is the pull, the probability that the organisational reliability maturity behaviours would either improve or retrogress. R is the highest average score: the score for the assigned maturity level, while Ri is the average score for the maturity level under consideration and is unique for each maturity level. The chapter thereafter used this calculation to demonstrate how the framework could be used to perform a health assessment and understand the current organisational reliability maturity position. Furthermore, the chapter described how the formula and the framework for organisational reliability maturity (FORM) could be used to predict the future of organisations. It could tell, based on current behaviours, that an organisation could potentially experience a catastrophic failure, or that the organisation is on a path of potential improvement in its organisational reliability maturity. In addition, the chapter demonstrated how the formula and the framework for organisational reliability maturity (FORM) could be used to benchmark organisations internally and externally. With these, the chapter demonstrated that the mindfulness of organisations can indeed be measured.

Finally, the chapter answered the second question “can these measurements help diverse organisations become more mature?” To achieve this, the chapter used individual examples from the different organisations to describe in details how the framework for organisational reliability maturity (FORM) could be used in conjunction with the organisational reliability maturity model (ORM^2) to suggest organisational reliability maturity improvement enhancing behaviours, as well as potential organisational reliability maturity improvement limiting behaviours. These are aimed at improving the organisations and organisational learning. This model and framework was used in eight different organisations and three different industries with similar results. The organisations, with diversities in size, age, and geographical spread were purposively selected to enhance data robustness and quality.

Chapter six shall summarize and conclude this research. It shall outline the scope and limitations of this research. It shall highlight the contributions of this research to existing knowledge and the new knowledge it has created. Finally it shall outline the scope for future studies.

CHAPTER SIX

DISCUSSION, CONCLUSION AND FUTURE WORK

Chapter five used the results obtained by this research to provided answers to the research questions. To answer the first question *"... can the reliability of organisations be measured?"* the chapter developed the Organisational Reliability Maturity Model (ORM^2) to help organisations measure their level of maturity in terms of organisational reliability. The chapter also demonstrated how to use the ORM^2 to measure and track their level of maturity over time. To answer the second question *"can these measurements help diverse organisations become more mature?"* chapter five developed the Framework for Organisational Reliability Maturity (FORM) to help organisations in self appraisals. The chapter also demonstrated how FORM could be used by organisations in internal and external benchmarking, to predict future behaviours, and to recommend specific behaviours to adopt or eliminate in their march towards performance improvement. Chapter six shall summarize the research. It shall outline the contributions of the research to the academic world and to the society. Finally, chapter six shall identify the limitations of this research as well as the scope for future studies.

6.1 Discussion

The aim of this research is to develop a harmonized framework for organisational reliability measurement that could be applied towards organisational maturity improvement. To achieve this, the research sets out to investigate if the reliability of organisations could be measured and if so, if the measurement could be standardized and applied to help diverse organisations become more mature.

This research is necessitated by the accelerated incidences of disasters over the last century with massive impacts on people, the environment and organisations. These disasters could not be predicted, but became subjects of retrospective predictability. The research notes that this increased incidences of disasters coincided with a period of exponential complex technological advancement within organisations, as well as a period characterised by tighter system and process coupling and interdependence. Despite this increased disasters, complexities in technology, and tighter interdependencies, the research notes that certain organisations, the high reliability organisations have continued to operate at top quartile level in organisational reliability and safety. Despite their very high potential for disasters, they continuously avoid failures, or are designed such that failures, should they occur, do not result in disasters. Should disasters occur, they are resilient enough to withstand the consequences. The research therefore hypothesises that developing a measurement framework for high reliability organisations, and extending this framework to diverse organisations could potentially help reduce the incidences of disasters.

This research argues that by extending the behaviours of these high reliability organisations to diverse organisations, organisations would become more mature and disasters would be prevented. The research therefore set out to collect a balanced data set that would help it to develop a standardized organisational reliability framework. Using the purposive sampling technique, the research obtained data from eight organisations in three industries and across two continents. The organisations were selected such that they contrast and complement one another in terms of type, size of organisation, age of organisation, and its geographical spread. The respondents were demographically stratified in terms of number of years of experience in the industry, responsibilities within their organisation and gender; the reasons for this stratification being to deepen the diversity of responses as much as possible.

The research was conducted using a mixed method design. This methodical choice was informed by the pragmatist philosophy adopted by the research. To effectively answer the exploratory research questions that seek to uncover the extent to which organisational reliability could be measured, as well as of the measurement could be adopted to enhance the maturity of diverse organisations, delved into a positivist philosophy to establish objective facts. This was achieved with the help of secondary sources and questionnaires administered anonymously. These objective facts alone could not answer the research questions, neither could they capture the subjective realities inferred through the feelings, intuitions, experiences nuances, and individual world views of the social actors involved in the organisation. Interpretivism through interviews was therefore introduced to capture the subjective ontologies involved with the organisations and the members of the organisations. The interviews were designed to delve deeper into the hearts and minds of the respondents, to peel away their biases and gain better insights into the underlying causative factors and mechanisms that may have influenced their responses in the questionnaires. The survey was conducted with the same time horizon, and the sample size determined through a combination of the mathematical relationship between the standard deviation, confidence level and confidence interval all in a bid to enhance the reliability and validity of the results.

The results show a similar distribution of the demographic in terms of responsibilities and number of years of experience in the industry among all the organisations surveyed; a fact that adds to the validity of the research. In most the organisations surveyed, there was often a sharp divide between the responses of the managers and that of the subordinates. This sharp divide indicates a huge schism between the different strata of the organisations, both in terms of communicating, understanding, and implementing the processes required to exhibit the high reliability behaviours. It highlights the differences in perspectives and world views of the people in different strata of the organisations. Secondly, it justifies the need of this research to stratify the respondents so as to obtain a balanced and diversified set of responses. Finally, obtaining similar responses from diverse organisations indicates that the research has achieved one of the things it set out to achieve at the beginning, all enhancing the validity of this research. Trick questions were introduced throughout the research to further enhance validity. These were similar questions worded differently to test the comprehension of the respondents, as well as verify that the responses are true reflections of the respondents' opinions. The results show that the responses from the trick questions were similar with the original questions and this is common across the organisations.

The research used the questionnaire to develop the Organisational Reliability Maturity Model (ORM^2) to assess the level of maturity of organisations in terms of organisational reliability, and to track their level of organisational reliability maturity over time. The Organisational Maturity Model (ORM^2) leverages on the HRO theory and identified specific reliability enhancing behaviours in organisations for each of the five HRO principles. The model, also referred to as the 5S model, maps the organisational reliability behaviours into five maturity levels and proposes what behaviours would be expected from organisations in different maturity levels.

The research used the results to develop the Framework for Organisational Reliability Maturity (FORM) to assess organisations with respect to organisational reliability. The FORM is designed for use by organisations in benchmarking, to predict future behaviours, and to recommend specific behaviours to adopt or eliminate in their march towards organisational learning and performance improvement. The predictive feature is especially useful if disasters must be avoided. The normally retrospective predictability disaster causative cues would be discovered and mitigated before the disaster could occur.

The research hopes that this work would not only expand existing knowledge in high reliability organisations, it would contribute to the reduction of disasters and therefore help to make the world safer and organisations more resilient.

Contributions of Research

Although a lot of work exists in HRO theory, this research identified a number of gaps. First most of the works were done in single organisations; there is no empirical evidence to indicate the existence of research in diverse organisations to test the HRO theory in different environments at the same time. With most of the work performed in silos, there is no evidence that it could be replicated in different organisations under different circumstances. Secondly, most of the existing research is limited to certain organisations: the traditional high reliability organisations. This disregards the fact that most catastrophic disasters in recent times were recorded in organisations mostly outside the traditional HROs such as oil and gas industries. Furthermore, most of the existing works were reactive in nature, retrospectively studying organisations after catastrophic incidents have occurred, and mostly from a theoretical perspective. A research that could potentially predict the potential of these disasters to occur would benefit humanity. Finally, this research observed that there were no existing studies that show how to measure the reliability of the organisations, or how the organisations can sustain their levels of reliability or improve through the stages of maturing towards higher levels of reliability. Filling these gaps would contribute to the academic world, benefit organisations, and help preserve humanity.

To fill these gaps, this research was conducted across eight different organisations in three different industries, in two continents and within the same time horizon to enhance diversity and increase the quality and validity of the assumptions and results. Expanding the research to diverse organisation mostly outside the traditional HROs would enhance the generalisability of the results, assumptions and conclusions. It would also provide evidence of a generalizable empirical research that addresses the concerns of Bundy et al (2017), Levenson et al (2009), and Bigley & Roberts (2001). They had observed the lack of specificity of existing research in the HRO theory, the abstract nature of the theory, and the need for a "comprehensive and detailed treatment" of high reliability organisations. This research fills these gaps and therefore expands existing knowledge in the HRO theory. The diversity of the organisations studied also enhances the generalizability of the HRO theory.

In addition to enhancing existing research, extending the research to organisations outside the traditional HROs is invaluable both to organisations and to humanity in general. As stated earlier, and discussed in details in sections two and three, a lot of the disasters over the past century has been in organisations outside the traditional HROs. These disasters have resulted in lots of fatalities, long and short term injuries, huge financial losses, and massive environmental impacts. Some organisations could not survive some of the disasters, and their demise meant massive job losses. Some people, communities, organisations, and certain habitats are still suffering from the impact of some of these disasters, decades after they occurred. Any research such as this that aims to help diverse organisations both within and outside the traditional HROs improve their reliability and potentially reduce disasters would therefore be invaluable both to the organisations, and to the society at large.

The model (ORM^2) and the framework (FORM) developed by this research filled the two final gaps of the retrospective predictability and the inability of previous research to proffer a methodical and empirical approach to the study of HROs. These are invaluable to the academia, organisations, and to the society. The model and the framework expand existing knowledge in the HRO theory and organisational learning. They also open up new areas for future researchers to develop further. The predictability ability of the framework means that organisations are better equipped to act to improve themselves and forestall catastrophic failures and disasters. This, by extension, means that the potential for disasters are reduced in organisations; the potential for fatalities, environmental pollution, financial loss, and organisation demise are also reduced. Similarly, the framework and the model help in organisational learning. Organisations are able to adopt a standardized and empirical method to assess their organisational reliability. They are also able to identify best in class behaviours and benchmark against those best in class behaviours. They are able to learn from highly reliable organisations and begin to design their organisations towards higher reliability. Considering that organisations with higher reliability have less potential for disasters, it therefore follows that this research would potentially help reduce the incidences of disasters and help protect organisations, the environment, and humanity in general.

Limitations of Research

This research was conducted with special consideration to diversity in terms of organisational size, age of operations and geographical spread. For each large organisation, a smaller one was purposively sampled; for each old and well established organisation, a relatively newer one was purposively sampled; and for each organisation with international spread, a relatively localized organisation was purposively sampled. Despite the best intentions and high confidence level of this research, it cannot claim that eight organisations and three industries is an accurate representation of all organisations and industries.

Another limitation is the inability of this research to guarantee success of similar research in other organisations and industries not surveyed. Although this research has high hopes in its ability to be replicated in different organisations and in diverse industries, it cannot completely guarantee that it could be seamlessly implemented in other industries. It cannot also guarantee that the results would be a reflection of the results from other industries and organisations not yet researched. This research could be conducted in different organisations and under different time horizons with different results.

The concept of high reliability organisation was discussed in the questionnaire and this could potentially pose another limitation. Some could argue that by reading the research perspectives on high reliability organisations as outlined on page two of the questionnaire, the respondent could become biased towards those definitions and could therefore tailor the responses to agree with or reject the perspectives. This is however hard to overcome as these definitions are standard and are easily assessable in any paper or books about HROs. Moreover, where the definitions are not provided in the questionnaires, some respondents might seek definitions from the internet or books, a situation that could become frustrating for some respondents, thereby reducing participation. Finally, the definitions enhance reliability by standardizing the meanings for all respondents, thereby limiting second guessing.

The research made a lot of effort to describe the validity of the research. Most of this was done through content validity. It described validity in terms of the ability of the questionnaire to provide adequate coverage of the research objectives and questions. It also described validity in terms of the appropriateness of the pilot testing and its relationship with the main research. The research also described validity in terms of the uniformity of the responses from different strata in different organisations and industries. Finally, the research described validity in terms of the ability of the research to answer the research questions. It cited the development of the measurement framework and the reliability maturity model, and their successful application in eight different organisations as further proof of validity. A gap exists here to describe validity in statistical terms using methods such as factor analysis. This could potentially form a basis for future studies.

The final limitation lies in the use of gatekeepers. With limited access to some of the organisations as well as due to the logistical nightmare involved in the data gathering, the use of gatekeepers was the most practical means of survey distribution. The organisations were guaranteed anonymity in part to prevent their manipulation or influencing of the respondents. Anonymity means that there would be no benefits to the organisations for influencing the respondents: the organisations would not be associated with the results. Although the gatekeepers were vetted as people with integrity based on their organisations and positions within their respective organisations, the research cannot guarantee absolutely that the choice of respondents were not influenced by the gatekeepers or their organisations. Furthermore this research used gatekeepers to conform to the intended demographic spread. The demographic had been stratified to enhance diversity of data to reduce bias. While this research has a high confidence that this was done, based on the consistency of the results, it cannot guarantee that this stratification was implemented to perfection. These limitations present gaps in this study that could potentially open up opportunities for further research.

6.2 Conclusion

The research had set out to answer the research questions:

- To what extent can the reliability of organisations be measured?
- Can these measurements help diverse organisations become more mature?

The aim was to develop a harmonized framework for high reliability organisations and apply the HRO theory to improve the maturity of diverse organisations. It had hoped that by improving the maturity of diverse organisations, it would improve their reliability and safety, and therefore reduce the incidences of disasters that have increased exponentially within the last few decades. It also hoped that the organisational reliability measurement framework would have the ability to help organisations in assessments, benchmarking, predicting potential for improvement or regression, organisational improvement, and organisational learning.

The research provides evidence that the reliability of organisations can be measured and that these measurements can be used to improve the maturity of diverse organisations and in doing so arrived at the following conclusions.

- The reliability of organisations can be measured. By developing the Organisational Reliability Maturity Model (ORM^2) also referred to as the 5S model, and the Framework for Organisational Reliability Maturity (FORM), the research demonstrates that the reliability of organisations could be measured.
- The high reliability organisation theory can be applied to diverse organisations outside the industries traditionally studied by previous researchers. Researchers have often considered certain organisations for the application of the high reliability organisation theory. This research considers this mind set to be faulty given that most incidents and disasters in history have been in organisations outside these traditional high reliability organisations. By applying the theory to different organisations in diverse industries to achieve similar results, this research demonstrates the practicability of the theory in diverse organisations.
- A measurement framework could be developed to assess the maturity of organisations in terms of organisational reliability. Using the results, the

research describes how the measurement framework could be combines the maturity model to assess the positions of organisations on the organisational reliability maturity grid. The research demonstrates that organisations could assess their organisational reliability behaviour and determine the extent to which they are reliable.

- The measurement framework could be used in organisational benchmarking. Given the ability of the framework to be replicated in different organisations with similar results, the research therefore demonstrates the ability of the framework to be used to benchmark organisations internally, against peers, and against best in class.
- The framework could potentially predict the probability of organisations to face disasters. The pull relationship developed by the research identifies the potential for organisations to improve or retrogress in terms of organisational reliability. Retrospective predictability of disasters and the penchant for the high reliability organisation theory to discuss disasters after the fact have been a major gap in the previous studies. This research closes this gap and demonstrates that these events could be predicted based on current behaviours of the organisations.
- The framework could be utilized in organisational learning and to improve the reliability behaviours of organisations. The Organisational Reliability Maturity Model (ORM^2) clearly defines behaviours expected from organisations at each maturity model. The organisations could therefore use this model in conjunction with the assessment and pull characteristics of the Framework for Organisational Reliability Maturity to recommend desired level behaviours to improve the maturity of the organisation.
- A mindful organisation is a safe organisation; therefore applying the high reliability organisation theory to diverse organisations would enhance safety and reduce disasters. Finally the research correlated between organisational mindfulness and disaster prevention. The research demonstrates that most disasters in history have been in organisations outside the organisations traditionally studied as high reliability organisations. Since these traditional high reliability organisations have consistently avoided incidents and disasters,

applying the theory to diverse organisations in different industries, including those that have consistently witnessed incidents and disasters would reduce incidence of disasters. Combining the assessment, predictive and improvement features of the measurement framework in these organisations would therefore help eliminate the disasters and ultimately help make organisations, and by extension humanity safer.

6.3 Scope for Future Research

The limitations in section 6.2 present opportunities for future studies. A future research could seek to enhance the diversity of this research and expand the research into more organisations and more diverse industries. The more the organisations and industries studied, the more the validity of the findings. A future research could therefore extend the diversity and expand the study further into more industries and organisations with varying degrees of complexity, coupling, size, and age. Increasing the diversity of the study would enhance the chances of generalizability and standardization of the assumptions and conclusions reached in this study. On the hand, it could also potentially disprove these assumptions and conclusions.

Another opportunity for future study lies in the removal of gatekeepers. A more detailed study could be in the form of a series of action research, where the researchers would spend sometime within the organisations and observe the behaviours of the respondents first hand. The researchers would have access to the organisational structure and personnel information. Any research that would minimize the use of gatekeepers and reduce respondents' bias would help enhance the validity and deepen the quality of the research.

Another opportunity lies in the inclusion of more traditional high reliability organisations for triangulation. A future research could seek to test the applicability of this framework in more traditional high reliability organisation. The results could validate the HRO theory and form the benchmark behaviour for organisational reliability maturity level 5 *"summit".* It could on the other hand dispel the myth of "traditional HROs" and show that these organisations might not be as exemplary as currently perceived.

The final opportunity lies in the weighting scale for the high reliability organisation principles. This research assumes an equal weighting for each of the five HRO principles. It adopted this stance for the sake of simplicity and standardization. A future research might explore different weighting scales for different organisations in specific industries in line with prevailing priorities within those industries or organisations. Certain organisations might consider some principles as being more important than the others and this might influence their choice of weighting.

This research has clearly closed a lot of gaps in existing organisational research and opened up new areas of research. The research hopes that in coming years, some of the limitations and scope for future studies could be exploited to deepen the body of knowledge.

References

Argyris, C. (1977). Organisational learning and management information systems. Accounting, Organisations and Society, 2(2), 113-123.

Al-Dahash, H., Thayaparan, M., & Kulatunga, U. (2016). Understanding the terminologies: disaster, crisis and emergency. In proceedings of the 32nd ARCOM conference, ARCOM (pp. 1191-1200).

Alvani, S. M. (2008). Public Management. Nay Publications, Tehran.

Anderson, C. F. (2007). The New Orleans Hurricane Protection System: What went wrong and why? A report by the American Society of Civil Engineers, Hurricane Katrina External Review panel http://biotech.law.lsu.edu/katrina/reports/ERPreport.pdf, Retrieved July 7, 2017.

Andrews (2015). Shell Iriama. http://www.academicjournals.org/journal/JPAPR/article-full-text-pdf/3F5BE7F51539, Assessed July 15, 2017.

Antil, P. (1991). The maintenance organisational maturity grid. Maintenance Conference, March, COMAC Publications, Birmingham.

Aramo-Immonen, H. (2011). Mixed methods research design. In World Summit on Knowledge Society (pp. 32-43), Springer, Berlin, Heidelberg.

Armitage, K. C. (2007). The Landscape of Reform: Civic Pragmatism and Environmental Thought in America. American Studies, 48(1), 160-161.

Arturson, G. (April 1987). The tragedy of San Juanico--the most severe LPG disaster in history. Burns Incl Therm Inj. 13 (2): 87–102.

Ashley, H. M., Farris, R. K., & Richards, R. E. (2009). Achieving high reliability operations through multi-program integration. Sixth American Nuclear Society International Topical Meeting on Nuclear Plant Instrumentation, Illinois: LaGrange Park

ASIS (2005). Business Continuity Guideline: A Practical Approach for Emergency Preparedness, Crisis Management, and Disaster Recovery. American Society for Industrial Security, Virginia https://www.asisonline.org/Standards-Guidelines/Guidelines/Published/Pages/Business-Continuity-Guideline-A-Practical-Approach-for-Emergency-Preparedness-Crisis-Management-(Download).aspx, Assessed July 2, 2017.

Azzaro, J. A. (2005). Understanding a high performance university development organisation: leadership and best practices. A PhD thesis.

Aven, T., & Krohn, B. S. (2014). A new perspective on how to understand, assess and manage risk and the unforeseen. Reliability Engineering & System Safety, 121, 1-10.

Backlund, F., Chronéer, D., & Sundqvist, E. (2014). Project management maturity models – a critical review. A case study within Swedish engineering and construction organisations, Procedia-Social and Behavioural Sciences, 119, 837-846.

Baker, D. P., Day, R., & Salas, E. (2006). Teamwork as an essential component of high reliability organisations. Health Research and Educational Trust, 41 (4), 1576-1598.

Ballard, R. D. (1987). The Discovery of the Titanic. New York: Warner Books,

Barratt, N. (2010). Lost voices from the titanic: the definitive oral history. London: Random House.

Bartlett, W.B. (2011). Titanic: 9 hours to hell, the survivors' story. Stroud, Gloucestershire: Amberley Publishing.

Beadell, B. B, (2009). CMMI as contemporary iron cage: a grounded analysis from the perspective of practicing engineers in defence engineering. The school of education of the University of St. Thomas, St. Paul, Minnesota.

Bell, E., & Bryman, A. (2007). The ethics of management research: an exploratory content analysis. British Journal of Management, 18(1), 63-77.

Bell, J., & Waters, S. (2014). Doing your research project: a guide for first time researchers. Maidenhead.

Bellamy, G. T., Crawford, L., Marshall, L. H., & Coulter, G. A. (2005). The fail-safe schools challenge: leadership possibilities from high reliability organisations. Educational Administration Quarterly, 41(3): 383-412.

Berardi, P. J. (2010). Measuring high reliability characteristics of the organisation. US Kansas City Fire Department http://www.usfa.fema.gov/pdf/efop/efo44533.pdf, assessed
20th November 2016.

Bergström, J., van Winsen, R., & Henriqson, E. (2015). On the rationale of resilience in the domain of safety: A literature review. Reliability Engineering & System Safety, 141, 131-141.

Bernard, H. R. (2011). Research methods in anthropology: Qualitative and quantitative approaches. Rowman Altamira.

Bhaskar, R. (2008). A Realist Theory of Science (Radical Thinkers). London: Verso.

Bierly, P. E., & Spender, J. C. (1995) Culture and high reliability organisations: The case of a nuclear submarine. Journal of Management, 21 (4), 639-656.

Bigley, G. A., & Roberts, K. H. (2001). The incident command system: High-reliability organising for complex and volatile task environments. Academy of Management Journal, 44: 1281-1299.

Blackstock, D., Burquel, N., Comet, N., Kajaste, M., dos Santos, S.M., Marcos, S. & Sixto, L.C.V. (2012). Internal quality assurance benchmarking. Workshop report No. 20, European Association for Quality Assurance in Higher Education, Avenue de Tervuren 36-38-boite 4, 1040, Brussels, pp. 8.

Blaikie, N. (2007). Approaches to social enquiry: Advancing knowledge. 2nd ed., Cambridge: Polity Press.

Blaikie, N. (2009). Designing social research: The logic of anticipation. Cambridge: Polity Press.

Blank, R. (2004). The Basics of Reliability. New York: Productivity Press.

Bls.gov (2017). Fatal occupational injuries in 2016. US Bureau of Labour Statistics, https://www.bls.gov/iif/oshwc/cfoi/cfch0015.pdf, Assessed on May 9, 2017.

Bogdan, R. C., & Biklen, S. K. (1998). Qualitative research for education: An introduction to theory and methods. 3rd ed., Boston: Allyn and Bacon.

Bollinger, R.E., Clark, D.G., Dowell, A.M., Ewbank, R.M., Hendershot, D.C., Lutz, W. K., Meszaros, S.I., Park D.E., & Wixom, E.D. (1996). Inherently safer chemical processes: A life cycle approach, Boston, MA: American Institute of Chemical Engineers.

Borg, B. (2002). Predictive safety from near miss and hazard reporting. Resource document, Signal Safety & Training.

Borodzicz, E. P. (2005). Risk, Crisis & Security Management. Chichester: John Wiley & Sons Ltd.

BP (2005). Fatal Accident Investigation Report: Isomerization Unit Explosion Final Report, http://www.bp.com/liveassets/bp_internet/us/bp_usenglish/ Assessed July 6th 2017.

British Council (2012). Gender in Nigeria report 2012: Improving the lives of girls and women in Nigeria, https://www.britishcouncil.org/sites/default/files/british-council-gender-nigeria2012.pdf, assessed June 9th, 2017.

British Standard Institute (2010). Maintenance - Maintenance terminology, BS EN 13306:2010.

British Standard Institute (2014). Crisis management – guidance and good practice, BS 11200.

Broadribb, M. P. (2014). What have we really learned? Twenty five years after Piper Alpha. Process Safety Progress, 34(1), 16-23.

Broughton, E. (2005). The Bhopal disaster and its aftermath: a review. Environmental Health, 4(1), 6.

Brown, A. G. (1993). High reliability organisation: a review and critique of the work of Todd LaPorte's Berkeley Group, Oxford: Oxford Centre for Management Studies.

Brown, K.W., & Ryan, R.M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. Journal of Personality and Social Psychology, 84(4), 822–848.

Bryman, A. (2016). Social research methods. Oxford: Oxford University Press.

Bryman, A., & Bell, E. (2015). Business research methods. USA: Oxford University Press.

Bryman, A., & Cramer, D. (2002). Quantitative data analysis with SPSS release 10 for Windows: a guide for social scientists. Routledge.

Burnell, G., & Morgan, G. (1979). Sociological paradigms and organisational analysis: Elements of the sociology of corporate life.

Bundy, J., Pfarrer, M. D., Short, C. E., & Coombs, W. T. (2016). Crises and crisis management: Integration, interpretation, and research development. Journal of Management, 43(6), 1661-1692.

Busby, J. S. (2006). Failure to mobilize in reliability-seeking organisations: two cases from the UK railway. J Manage Stud; 43(6): 1375- 1393.

CAA (2017). The Skyway Code, Civil Aviation Authority. http://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=7919, Assessed August 12, 2017.

CAIB (2003). Decision making at NASA, Columbia accident investigation board report, chapter 6. http://s3.amazonaws.com/akamai.netstorage/anon.nasa-global/CAIB/CAIB_lowres_chapter6.pdf. Retrieved July 6th, 2017.

Calás, M. B., & Smircich, L. M. (1997). Postmodern management theory: History of management and thought. London: Dartmouth Publishing Company.

Camp, R. (1989). The search for industry best practices that lead to superior performance. New York, Productivity Press.

Chase, S. E. (2011). Narrative inquiry: Still a field in the making. The Sage handbook of qualitative research, 4, 421-434.

Chia, R. C. (2003). Organisation Theory as Postmodern Science. In C. Knudsen, & H. Tsoukas (Eds.), *Oxford Handbook of Organisation Theory*. (pp. 113-140). Oxford University Press.

CIA (2017). The World Factbook Central: Nigeria. Central Intelegence Agency. https://www.cia.gov/library/publications/the-world-factbook/geos/ni.html assessed August 9th 2017.

Ciravegna, L., & Brenes, E. R. (2016). Learning to become a high reliability organisation in the food retail business. Journal of Business Research, 69(10), 4499-4506.

Cohen, L., Manion, L., & Morrison, K. (1994). Educational research methodology. Athens: Metaixmio.

Coghlan, D. (2011). Action research: Exploring perspectives on a philosophy of practical knowing. Academy of Management Annals, 5(1), 53-87.

Coghlan, D., & Brannick, T. (2014). Doing action research in your own organisation. Sage.
Collins, H. (2010). Creative research: the theory and practice of research for the creative industries. Bloomsbury Publishing.

Costella, M. F., Saurin, T. A., and Guimaraes, L. B. (2009). A method for assessing health and safety management systems from the resilience engineering perspective, Safety Science, 47, 1056-1067.

Cox, S. (1999). The Titanic Story: Hard Choices, Dangerous Decisions. Chicago: Open Court Publishing.

Creswell, J. W. (2013). Research design: Qualitative, quantitative, and mixed methods approaches. London: Sage.

Creswell, J. W., & Clark, P. VL (2011). Designing and conducting mixed methods research, 2nd ed., London: Sage.

Crosby, P. B. (1979). Quality is free: the art of making quality certain, New York, NY: McGraw-Hill Companies.

Crossan, M. M., Lane, H. W., & White, R. E. (1999). An organisational learning framework: From intuition to institution. Academy of management review, 24(3), 522-537.

Crotty, M. (1998). The foundations of social research: Meaning and perspective in the research process. London: Sage.

Cullen Report (1990). The Hon. Lord W.D. Cullen public inquiry into the Piper Alpha Disaster. London: HMSO.

Davidmack (2014). The Swiss cheese model of accident causation. Licenced under Creative Commons BY-SA 3.0, Retrieved from https://commons.wikimedia.org/wiki/File:Swiss_cheese_model_of_accident_causation.png April 4, 2018.

Dawes, P. L. (2003). A model of the effects of technical consultants on organisational learning in high-technology purchase situations. The Journal of High Technology Management Research, 14(1), 1-20.

De Bruin, T., & Rosemann, M. (2005). Towards a business process management maturity model. In Bartmann, D., Rajola, F., Kallinikos, J., Avison, D., Winter, R., Ein-Dor, P, et al. (Eds.) *ECIS 2005 Proceedings of the Thirteenth European Conference on Information Systems*, 26-28 May 2005, Germany, Regensburg.

Dekker, S., Hollnagel, E., Woods, D. & Cook, R. (2008). Resilience Engineering: New directions for measuring and maintaining safety in complex systems Final Report December 2008.

De Vaus, D. (2014). Diversity and change in Australian families: Statistical profiles. Australian Institute of Family Studies. 2004.

Demir, C., & Kocabaş, İ. (2010). Project management maturity model (PMMM) in educational organisations. Procedia-Social and Behavioral Sciences, 9, 1641-1645.

Denzin, N. K., & Lincoln, Y. S. (2011). The Sage handbook of qualitative research. London: Sage.

Devine, D. J. (2002). A review and integration of classification systems relevant to teams in organisations. Group Dynamics: Theory, Research, and Practice, 6(4), 291.

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). Internet, phone, mail, and mixed-mode surveys: the tailored design method. Hoboken, New Jersey: John Wiley & Sons.

Easterby-Smith, M., Thorpe, R., & Jackson, P. R. (2012). Management research. London: Sage.

Edwards, D. W. (2005). Are we too risk-averse for inherent safety?: An examination of current status and barriers to adoption. Process Safety and Environmental Protection, 83(2), 90-100.

Emdat.be (2017). The International Disaster Database, Centre for Research on the Epidemiology of Disasters – CRED. www.emdat.be Assessed September 12, 2014.

Eriksson, P., & Kovalainen, A. (2015). Qualitative methods in business research: A practical guide to social research. London: Sage.

Eurocontrol (2009). White paper on resilience engineering for ATM, Cooperative Network Design. European Organisation for the Safety of Air Navigation (Eurocontrol).

Favaro, F. M., & Saleh, J. H. (2014). Observability-in-depth: an essential complement to the defense-in-depth safety strategy in the nuclear industry. Nuclear Engineering and Technology, 46(6), 803-816.

Favaró, F. M., & Saleh, J. H. (2015). Observability in depth: novel safety strategy to complement defence-in-depth for dynamic real-time allocation of defensive resources. Nutritional Care of the Patient with Gastrointestinal Disease, 109.

Fenton, N. E., & Pfleeger, S. L. (1996). Software metrics: A rigorous and practical approach. London: PWS.

Fernandez, O., Labib, A.W., Walmesly, R., & Petty, D. J. (2003). A decision support maintenance management system: development and implementation, International Journal of Quality & Reliability Management, 20(8), pp. 965-979.

Fireice (2008). Diagram of RBMK nuclear reactor schematic. Licenced under Creative Commons BY-SA 3.0, Retrieved from https://goo.gl/images/hTUiSy, April 3, 2018.

Fleming, M. (2000). Safety culture maturity model. Offshore Technology Report-Health and Safety Executive OTH.

Flick, U. (2015). Introducing research methodology: a beginners guide to doing a research project. London: Sage.

Flyvbjerg, B. (2011). Case study. In: N. K. Denzin and Y. S. Lincoln (eds.). The Sage Handbook of Qualitative Research, 4th ed. Thousand Oaks, CA: Sage, pp. 301–316.

Fontevecchia, F. (2013). BP fighting a two front war as Macondo continues to bite and production drops. https://www.forbes.com/sites/afontevecchia/2013/02/05/bp-fighting-a-two-front-war-as-macondo-continues-to-bite-and-production-drops/#302d5ceb458c, assessed July 8, 2017.

Foster, H.D. (1993): Resilience theory and system evaluation. In J.A. Wise, V. D. Hopkin and P. Stager (eds): Verification and Validation of Complex Systems: Human Factors Issues. Berlin: Springer, 35-60.

Frankel, A. S., Leonard, M. W., and Denham, C. R. (2006). Fair and just culture, team behaviour, and leadership engagement: The tools to achieve high reliability. Health Services Research, 41 (4), 1690-1709.

Gabriel, Y., & Griffiths, D. S. (2004). Stories in organisational research. In C. Cassell, & G. Symon (Eds.), Essential guide to qualitative methods in organisational research: 114-126. London: Sage.

Gilbert, D. T., & Malone, P. S. (1995). The correspondence bias. Psych. Bull. 117(1): 21-38.

Gilbertson, A., Kappia, J., Bosher, L., and Gibb, A. (2011). Preventing catastrophic events in construction, Health and Safety Executive 2011, RR834 Research Report.

Gill, J., & Johnson, P. (2010). Research methods for managers. London: Sage.

Grabowski, M., & Roberts, K. H. (2016). Reliability seeking virtual organisations: Challenges for high reliability organisations and resilience engineering. Safety Science.

Gross, R. (2015). Psychology: The science of mind and behaviour. 7th ed, Hodder Education.

Goddard, W., & Melville, S. (2004). Research methodology: An introduction. South Africa: Juta & Company.

Golafshani, N. (2003). Understanding reliability and validity in qualitative research. The qualitative report, 8(4), 597-606.

Greenberg, M. I. (2006). Encyclopedia of terrorist, natural, and man-made disasters. Jones & Bartlett Learning.

Guard, U. C. (2011). On Scene Coordinator Report Deepwater Horizon Oil Spill: Submitted to the National Response Team, September 2011. Retrieved July 8, 2017.

Gumusluoglu, L., Karakitapoğlu-Aygün, Z., & Hirst, G. (2013). Transformational leadership and R&D workers' multiple commitments: Do justice and span of control matter? Journal of Business Research, 66(11), 2269-2278.

Haavik, T. K., Antonsen, S., Rosness, R., & Hale, A. (2016). HRO and RE: a pragmatic perspective. Safety Science.

Haddon, J. W. (1970). On the escape of tigers: an ecologic note. American Journal of Public Health and the Nations Health, 60(12), 2229-2234.

Haddon, J. W. (1980). The basic strategies for reducing damage from hazards of all kinds. Hazard prevention, 16(1), 8-12.

Hales, D. N., & Chakravorty, S. S. (2016). Creating high reliability organisations using mindfulness. Journal of Business Research, 69(8), 2873-2881.

Harré, R. (2001). How to change reality: Story vs. structure-A debate between Rom Harré and Roy Bhaskar. After postmodernism: An introduction to critical realism, 22-38.

Harrison, H., Birks, M., Franklin, R., & Mills, J. (2017). Case Study Research: Foundations and Methodological Orientations. Forum: Qualitative Social Research, 18(1), Art. 19.

Harvey, E.J., Waterson, P. and Dainty, A.R. (2016). Applying HRO and resilience engineering to construction: Barriers and opportunities. Safety Science.

Harvey, E. J., Waterson, P., & Dainty, A. R. (2016). Applying HRO and resilience engineering to construction: Barriers and opportunities. Safety Science.

Hassard, J., & Pym, D. (2012). The theory and philosophy of organisations: critical issues and new perspectives. London: Routledge.

Hatch, M. J., & Cunliffe, A. L. (2006). Organisation Theory: Modern, Symbolic and Postmodern Perspectives. Oxford: Oxford University Press.

Hendershot, D.C. (1998). Safety through design in the chemical process industry: inherently safer process design. In Proceedings of 1997 Symposium: Benchmarks for World Class Safety through Design, Bloomingdale, IL, Aug. 19-20, 1997, Institute for Safety Through Design, National Safety Council, Itasca, IL. pp. 53–67.

Hofmann, D., Jacobs, R., and Landy, F. (1995). High reliability process industries: Individual, micro and macro organisational influences on performance. Journal of Safety Research, 26 (3), 131-149.

Hollnagel E. (2006). Resilience: the challenge of the unstable. In Hollnagel E, Woods D & Leveson N (ed.). Resilience engineering. Burlington (VT): Ashgate, 2006, pp. 9–18

Hollnagel, E., Woods, D., & Leveson, N. (2008). Resilience engineering in a nutshell. Resilience engineering perspectives, 1, Aldershot, UK: Ashgate.

Hollnagel, E., & Fujita, Y. (2013). The Fukushima disaster: systemic failures as the lack of resilience. Nuclear Engineering and Technology, 45(1), 13-20.

Hopkins, A. (2007). The problem of defining high reliability organisations, Working Paper 51, The Australian National University.

Hopkins, A. (2009). Failure to learn: The BP Texas City refinery disaster, Australia: CCH Australian Limited.

Hopkins, A. (2014). Issues in safety science. Safety science, 67, 6-14.

Howells, R. (1999). Myth and the Titanic. In The Myth of the Titanic. London: Palgrave Macmillan.

Huang, D. & Zhang, W. (2010). CMMI in medium & small enterprises: problems and solutions, in: Proceedings of the 2nd IEEE International Conference on Information Management and Engineering, 2010, pp. 171–174.

Huber, G. P. (1991). Organisational learning: The contributing processes and the literatures. Organisational Science 2(1): 88-115.

Hutchings, D. F., & De Kerbrech, R. P. (2011). RMS Titanic 1909-12 (Olympic Class): Owners' workshop manual. An insight into the design construction and operation of the most famous passenger ship of all time, London: Zenith Press.

IET (2017). Glossary of safety terminology. Health & Safety Briefing No. 00, The Institute of Engineering and Technology.

INSAG-7 (1992). The Chernobyl Accident: Updating of insag-1, a report by the international nuclear safety advisory group, international atomic energy agency, Vienna, Austria.

INSAG-10 (1996) Defence in depth in Nuclear safety, a report by the international nuclear safety advisory group, international atomic energy agency, Vienna, Austria

Introna, V., Cesarotti, V., Benedetti, M., Biagiotti, S., & Rotunno, R. (2014). Energy Management Maturity Model: an organisational tool to foster the continuous reduction of energy consumption in companies. Journal of Cleaner Production, 83, 108-117.

Invernizzi, D. C., Locatelli, G., & Brookes, N. J. (2017). How benchmarking can support the selection, planning and delivery of nuclear decommissioning projects. Progress in Nuclear Energy, 99, 155-164.

Ishizaka, A., & Labib, A. (2014). A hybrid and integrated approach to evaluate and prevent disasters. Journal of the Operational Research Society, 65(10), 1475-1489.

Jalongo, M. R., & Saracho, O. N. (2016). Writing for Publication: Transitions and Tools that Support Scholars' Success. Springer.

Jeffcott, S., Pidgeon, N., Weyman, A., and Walls, J. (2006.) Risk, trust, and safety culture in UK train operating companies. Risk Anal; 26(5): 1105-1121.

Kahn, W. A., Barton, M. A., & Fellows, S. (2013). Organisational crises and the disturbance of relational systems. Academy of Management Review, 38: 377-396.

Kelemen, M. L., & Rumens, N. (2008). An introduction to critical management research. London: Sage.

Keller, P. (2004). Managing the unexpected in prescribed fire and fire use operations: a workshop on the high reliability organisation. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Kervin, L. K., Vialle, W. J., Herrington, J. A. & Okely, A. D. (2006). Research for Educators. South Melbourne, VIC: Thomson/Social Science Press.

Ketokivi, M., & Mantere, S. (2010). Two strategies for inductive reasoning in organisational research. Academy of Management Review, 35(2), 315-333.

Kilduff, M., & Mehra, A. (1997). Postmodernism and organisational research. Academy of Management Review, 22(2), 453-481.

Kim, H., Haugen, S., & Utne, I. B. (2016). Assessment of accident theories for major accidents focusing on the MV SEWOL disaster: Similarities, differences, and discussion for a combined approach. Safety science, 82, 410-420.

Kim, J.-Y. J. & Miner, A. S. (2007). Vicarious learning from the failures and near-failures of others: Evidence from the U.S. commercial banking industry. Academy of Manage. Journal 50(3): 687-714.

Khan, F. I., & Amyotte, P. R. (2003). How to make inherent safety practice a reality. The Canadian Journal of Chemical Engineering, 81(1), 2-16.

Kletz, T. A. (1978). What you don't have, can't leak. Chemistry and Industry, 6, 287-292.

Kletz, T. A., & Amyotte, P. (2010). Process plants: A handbook for inherently safer design. CRC Press.

Knudsen, C. (2002). Pluralism, scientific progress and the structure of organisation studies (No. 2002-05). Department of Industrial Economics and Strategy, Copenhagen Business School.

Kosieradzka, A. (2017). Maturity Model for Production Management. Procedia Engineering, 182, 342-349.

Kuhn, T. S. (1970). The Structure of Scientific Revolutions, 2nd enl. ed. University of Chicago Press.

Labaka, L., Hernantes, J., & Sarriegi, J. M. (2015). Resilience framework for critical infrastructures: An empirical study in a nuclear plant. Reliability Engineering & System Safety, 141, 92-105.

Labib, A. (2014). Learning from failures: decision analysis of major disasters. Amsterdam: Elsevier, Butterworth-Heinemann.

Labib, A., & Harris, M. J. (2015). Learning how to learn from failures: the Fukushima nuclear disaster. Engineering Failure Analysis, 47, 117-128.

Labib, A., & Read, M. (2015). A hybrid model for learning from failures: the Hurricane Katrina disaster. Expert Systems with Applications, 42(21), 7869-7881.

Labib, A. & Read, M. (2013). Not just rearranging the deckchairs on the Titanic: Learning from failures through Risk and Reliability Analysis. Safety science, 51(1), pp.397-413.

Labib, A., & Read, M. (2015). A hybrid model for learning from failures: the Hurricane Katrina disaster. Expert Systems with Applications, 42(21), pp.7869-7881. doi: 10.1016/j.eswa.2015.06.020

Langer, E. J. (2000). Mindful learning. Current Directions in Psychological Science, 9(6), 220-223.

Langer, E. J. (2014). Mindfulness: 25th anniversary ed. A Merloyd Lawrence *Book*, Da Capo Lifelong Books.

La Porte, T., & Consolini, P. (1998). Theoretical and operational challenges of ‘high reliability organisations’: air traffic control and aircraft carriers, International Journal of Public Administration, 21 (6-8), 847-852.

Le Coze, J. C. (2016). Vive la diversité! High Reliability Organisation (HRO) and Resilience Engineering (RE). Safety Science.

Lekka, C. (2011). High reliability organisations, a review of the literature, Health and Safety Laboratory for Health and Safety Executives, RR 899.

Lekka, C., and Sugden, C. (2011). Successes and challenges of implementing high reliability principles: a case study of a UK oil refinery, Process Safety and Environmental Protection.

Leveson, N., Dulac, N., Marais, K., & Carroll, J. (2009). Moving beyond normal accidents and high reliability organisations: A systems approach to safety in complex systems. Organisation Studies, 30, 227-249.

Levinthal, D., & Rerup, C. (2006). Crossing an apparent chasm: Bridging mindful and less-mindful perspectives on organisational learning. Organisation science, 17(4), 502-513.

Li, W., Zhang, L. and Liang, W. (2017). An Accident Causation Analysis and Taxonomy (ACAT) model of complex industrial system from both system safety and control theory perspectives, Safety science, 92, pp.94-103.

Lin, Z., Zhao, X., Ismail, K, & Carley, K. M. (2006). Organisational design and restructuring in response to crises: Lessons from computational modelling and real-world cases. Organisation Science, 17: 598-618.

Littlejohn, A., Margaryan, A., Vojt, G., & Lukic, D. (2017). Learning from Incidents Questionnaire (LFIQ): The validation of an instrument designed to measure the quality of learning from incidents in organisations. Safety science, 99, 80-93.

Lodico, M. G., Spaulding, D. T., & Voegtle, K. H. (2010). Methods in educational research: From theory to practice (Vol. 28). John Wiley & Sons.

Lukic, D., Littlejohn, A., & Margaryan, A. (2012). A framework for learning from incidents in the workplace. Safety Science, 50(4), 950-957.

Madsen, P., Desai, V., Roberts, K., and Wong, D. (2006). Mitigating hazards through continuing design: the birth and evolution of a paediatric intensive care unit, Organisation Science, 17 (2), 239-248.

Marcoulides, G. A. (Ed.). (1998). Modern methods for business research. Psychology Press.

Marcus, A. A., & Nichols, M. L. (1999). On the edge: Heeding the warnings of unusual events. Organisation Science, 10: 482-499.

Marquardt, M. J. (2011). Building the learning organisation: Mastering the five elements for corporate learning. Hachette UK.

May, T. (2011). Social research: Issues, methods and process. 4th ed., Berkshire, UK: Open University Press, McGraw-Hill Education.

Mayo, A., & Lank, E. (1994). The Power of Learning: A guide to gaining competitive advantage. London: Institute of personnel and development.

Medvedev, Z. A. (1990). The Legacy of Chernobyl. First American edition, New York: W. W. Norton & Company.

Miller, B. M., and Horsley, S. J. (2009). Digging deeper: crisis management in the coal industry, Journal of Applied Communication Research; 37(3): 298-316.

Mitchell, V. (1996). Assessing the reliability and validity of questionnaires: an empirical example. Journal of Applied Management Studies, 5, 199-208.

MFA (2009). Chernobyl disaster April 2009: why are the consequences still observed http://chernobyl.undp.org/russian/docs/belarus_23_anniversary.pdf. Retrieved April 28, 2017

Mkansi, M., & Acheampong, E. A. (2012). Research philosophy debates and classifications: students' dilemma. Electronic Journal of Business Research Methods, 10(2), 132-140.

Mogford, J., (2005). Fatal Accident Investigation Report: Isomerization Unit Explosion Final Report, Texas City, Texas, USA. http://people.uvawise.edu/pww8y/Supplement/-ConceptsSup/Work/WkAccidents/BPTxCityFinalReport.pdf Assessed July 6th, 2017

Montagna, P. (1997). Modernism vs postmodernism in management accounting. Critical Perspectives on Accounting, 8(1-2), 125-145.

Morrish, C. (2017). Incident prevention tools–incident investigations and pre-job safety analyses. International Journal of Mining Science and Technology, 4(27), 635-640.

Moura, R., Beer, M., Patelli, E., Lewis, J., & Knoll, F. (2016). Learning from major accidents to improve system design. Safety science, 84, 37-45.

NASA (1986). Challenger crew in the white room before the launch. Published by Kennedy Space Centre, under Creative Commons public domain, Retrieved from https://www.flickr.com/photos/nasacommons, April 3, 2018.

NASA (1986) Space Shuttle Challenger explodes shortly after take-off. Published by Kennedy Space Centre, under Creative Commons public domain, Retrieved from https://www.flickr.com/photos/nasacommons, April 3, 2018

NASA (2007) Official portrait of the Columbia crew, published by NASA under Creative Commons public domain. Retrieved from http://nix.larc.nasa.gov/info;jsessionid=7qq0j1qrh8h4c?id=MSFC-0701327&orgid=11, April 3, 2018.

NASA (2007) Close-up photo of the left bipod foam ramp that caused the destruction of the Space Shuttle Columbia. Published by NASA under Creative Commons public domain, https://commons.wikimedia.org/w/index.php?curid=3154757 Retrieved April 3, 2018.

Nationmaster (2017). Nigeria labour statistics. http://www.nationmaster.com/country-info/profiles/Nigeria/Labor, assessed August 2, 2017.

National Response Team (2011). On Scene Coordinator Report on Deepwater Horizon Oil Spill, submitted to the National Response Team (PDF). September 2011.

Neuhauser, C. (2004). A maturity model: does it provide a path for online course design? J. Interact. Online Learn. 3.

Neuman, L. W. (2002). Social research methods: Qualitative and quantitative approaches. London: Pearson.

Nikkhou, S., Taghizadeh, K., & Hajiyakhchali, S. (2016). Designing a Portfolio Management Maturity Model (Elena). Procedia-Social and Behavioral Sciences, 226, 318-325.

Norris, C. (2007). Ontology. Dictionary of critical realism, 334-338.

Oliveira, M. A., Lopes, I. and Figueiredo, D. L. (2012). Maintenance management based on organisation maturity level, International Conference on Industrial Engineering and Operations Management ICIEOM July 9 – 11.

O'Neil, P. D. (2011). High reliability systems and the provision of a critical transportation service, J Contingencies and Crisis Management; 19(3): 158-168.

Pasha, M., Zaini, D., & Shariff, A. M. (2017). Inherently safer design for heat exchanger network. Journal of Loss Prevention in the Process Industries, 48, 55-70.

Patton, M. Q. (1990). Qualitative evaluation and research methods. New York: SAGE.

Peters, L. D., Pressey, A. D., Vanharanta, M., & Johnston, W. J. (2013). Constructivism and critical realism as alternative approaches to the study of business networks: Convergences and divergences in theory and in research practice. Industrial Marketing Management, 42(3), 336-346.

Perrow, C. (1984). Normal accidents: Living with high-risk technologies. New York: Basic Books.

Perrow, C. (1994). The limits of safety: the enhancement of a theory of accidents. Journal of contingencies and crisis management, 2(4), 212-220.

Pfeffer, J. (1993). Barriers to the advance of organisational science: Paradigm development as a dependent variable. Academy of management review, 18(4), 599-620.

Polyani, M. (1958). Personal knowledge. Towards a post-critical philosophy, London: Routledge.

PC & Rogers, W. P. (1986). Report of the presidential commission on the space shuttle challenger accident. https://history.nasa.gov/rogersrep/genindex.htm retrieved July 6th 2017.

Proshare (2017). NB accounts for 60% market share in brewery industry. https://www.proshareng.com/news/Investors%20NewsBeat/NB-accounts-for-60Percent-market-share-in-brewery-industry----/6559, Assessed March 12th 2017.

Pidgeon, N., & O'Leary, M. (2000). Man-made disasters: why technology and organisations (sometimes) fail. Safety Science, 34(1), 15-30.

Puleo, S. (2004). Dark Tide: The Great Boston Molasses Flood of 1919. Beacon Press.
Rasmussen, J. (1994). Risk management, adaptation, and design for safety. In Future risks and risk management (pp. 1-36). The Netherlands: Springer.

Rasmussen, J. (1994). Risk management, adaptation, and design for safety. In: Sahlin, N.E., Brehmer, B. (Eds.), Future Risks and Risk Management. Kluwer, Dordrecht.

Rasmussen, J. (1997). Risk management in a dynamic society: a modelling problem. Safety science, 27(2), 183-213.

Reason, P. (2006). Choice and quality in action research practice. Journal of management inquiry, 15(2), 187-203.

Reason, J. (2016). Managing the risks of organisational accidents. London: Routledge.

Reed, M. (2009). Critical realism: Philosophy, method, or philosophy in search of a method. The SAGE handbook of organisational research methods, 430-448.

Righi, A. W., Saurin, T. A., & Wachs, P. (2015). A systematic literature review of resilience engineering: Research areas and a research agenda proposal. Reliability Engineering & System Safety, 141, 142-152.

Riley, W. (2009). High reliability and implications for nursing leaders, J Nurs Manag; 17(2): 238-246.

Roberts, K. (1990). Some characteristics of one type of high reliability organisation. Organisation Science, 1 (2), 160-176.

Roberts, K. (1993). Cultural characteristics of reliability enhancing organisations, Journal of Managerial Issues, 5 (2), 165-181.

Roberts, K. H. & Rousseau, D. M. (1989). Research in nearly failure-free, high-reliability organisations: having the bubble. IEEE Transactions on Engineering Management, 36: 132–139.

Roberts, K., Stout, S., & Halern, J. (1994). Decision dynamics in two high reliability military organisations, Management Science vol. 40(5), pp. 614-24.

Roberts, K. H., & Bea, R. (2001). Must accidents happen? Lessons from high-reliability organisations, Academy of Management Executive, 15 (3), 70-79.

Roberts, K., Desai, V., and Madsen, P. (2005) Reliability enhancement and demise at Back Bay Medical Centre Children's hospital, In P. Carayon (Ed.), Handbook of human factors and ergonomics in healthcare and patient safety (pp. 249-258). London: Erlbaum.

Rochlin, G. I. (1993) Defining high reliability organisations in practice: a taxonomic prologue. In K. H. Roberts (Ed.), New challenges to understanding organisations (pp. 11-32), New York: Macmillan.

Rogers, J. D., Kemp, G. P., Bosworth, H. J., & Seed, R. B. (2015). Interaction between the US Army Corps of Engineers and the Orleans Levee Board preceding the drainage canal wall failures and catastrophic flooding of New Orleans in 2005. Water Policy, 17(4), 707-723.

Rosencranz, A. (1988). Bhopal, Trasnational Corporations, and hazardous technologies. Ambio, 17(5), 336-341.

Rosness, R., Grøtan, T.O., Guttormsen, G., Herrera, I.A., Steiro, T., Størseth, F., Tinmannsvik, R.K., Wærø, I. (2010). Organisational Accidents and Resilient Organisations: Six Perspectives Revision 2 (SINTEF Report).

Ross, P. (2008). The night the sea caught fire: Remembering Piper Alpha. http://www.scotsman.com/lifestyle/the-night-the-sea-caught-fire-remembering-piper-alpha-1-1433754, Retrieved 3 June 2017.

Ross, L. & Nisbett, E. (1991). The Person and the Situation: Perspectives of Social Psychology. New York: McGraw-Hill.

Rougier, J., Sparks, S., Aspinall, W., Cornell, S., Crosweller, S., Edwards, T., Freer, J., Hill, L., & Hincks, T., (2010). SAPPUR: NERC scoping study on uncertainty and risk in natural hazards, BRISK, University of Bristol.

Roux-Dufour, C. (2000). The paradox of high reliability organisations: a Weickian perspective, France: Ecole de Management de Lyon.

Roux-Dufort, C. (2007). Is crisis management (only) a management of exceptions? Journal of Contingencies and Crisis Management, 15: 105-114.

Rudolph, J. W., & Repenning, N. R. (2002). Disaster dynamics: Understanding the role of interruptions and stress in organisational collapse. Administrative Science Quarterly, 47: 1-30.

Ryan, P. R. (1985). The Titanic Tale: Oceanus. Woods Hole Oceanographic Institution. 4 (28) Woods Hole, MA.

Saadat, V., & Saadat, Z. (2016). Organisational Learning as a Key Role of Organisational Success. Procedia-Social and Behavioral Sciences, 230, 219-225.

Saunders, M., Lewis, P. and Thornhill, A. (2016). Research methods for business students. Harlow: Pearson Education Limited

Saleh, J. H., Marais, K. B., Bakolas, E., & Cowlagi, R. V. (2010). Highlights from the literature on accident causation and system safety: Review of major ideas, recent contributions, and challenges. Reliability Engineering & System Safety, 95(11), 1105-1116.

Saleh, J. H., & Pendley, C. C. (2012). From learning from accidents to teaching about accident causation and prevention: Multidisciplinary education and safety literacy for all engineering students. Reliability Engineering & System Safety, 99, 105-113.

Samuels, J. G. (2010). The application of high-reliability theory to promote pain management, J Nurs Adm; 40(11):471-6.

Sandbox Networks Inc, (2017). Oil spill and disasters. A statistics database. https://www.infoplease.com/world/disasters/oil-spills-and-disasters assessed on the 28th of June, 2017

Savioja, P., Norros, L., Salo, L., & Aaltonen, I. (2014). Identifying resilience in proceduralised accident management activity of NPP operating crews. Safety Science, 68, pp.258-274.

Shell (2015). Shell in Nigeria. http://www.shell.com/investors/news-and-media-releases/investor-presentations/2012-investor-presentations/sri-shell-operations-nigeria-10102012/_jcr_content/par/textimage.stream/1447704930330/47516b1ddb1865962427 7bd6dac9c0b1ee51dc10356ee93c9f9b574a0fbc9e78/overview-sri-shelloperationsnigeria.pdf, assessed June 9, 2017.

Schulman, P. R. (1993). The negotiated order of organisational reliability, Administration & Society; 25(3):353-372.

Schulman, P. (2008). Assessing NASA's safety culture: the limits and possibilities of high-reliability theory, Arjen Boin 2008; 68(6): 1050–1062.

Schutz, A. (1970). Alfred Schutz on phenomenology and social relations (Vol. 360). Chicago: University of Chicago Press.

Schyns, B., Paul, T., Mohr, G., & Blank, H. (2005). Comparing antecedents and consequences of leader–member exchange in a German working context to findings in the US. European Journal of Work and Organisational Psychology, 14, 1–22.

Sekaran, U., & Bougie, R. (2016). Research methods for business: A skill building approach. Chichester, UK: John Wiley & Sons

Silverman, D. (2013). Doing qualitative research: A practical handbook. New York: SAGE Publications Limited.

Sitkin, S. B. (1992). Learning through failure: The strategy of small losses. Research in Organisational Behavior. L. L. Cummings and B. M. Staw. Greenwich, CT, JAI Press. 14.

Sklet, S. (2006). Safety barriers: definition, classification, and performance. J. Loss Prevent. Process Ind. 19 (5), 494–506.

Snieder, R., & Larner, K. (2009). The art of being a scientist: A guide for graduate students and their mentors. Cambridge, UK: Cambridge University Press.

Smith, S. (2013) Determining Sample Size: How to Ensure You Get the Correct Sample Size https://www.qualtrics.com/blog/determining-sample-size/ Retrieved 3 June 2017

Stapelberg, R. F. (2009). Reliability and Performance in Engineering Design. Handbook of Reliability, Availability, Maintainability and Safety in Engineering Design, 43-294.

Starman, A. B. (2013). The case study as a type of qualitative research. Journal of Contemporary Educational Studies/Sodobna Pedagogika, 64(1).

Steen, E. V. D. (2016). A formal theory of strategy. Management Science, 63(8), 2616-2636.

Stralen, van, D., Calderon, R., Clements, P., Daniel, A., Rao, R., Padgett, J., Kausen, B., & Roberts, K. (2006). High reliability organisation methods facilitate initiation of mechanical ventilation in a paediatric nursing home, Society of Critical Care Medicine, 35th Critical Care Congress, San Francisco, California, January 7-11.

Stringfield, S. (1995). Attempting to enhance students' learning through innovative programs: the case for schools evolving into high reliability organisations. School Effectiveness and School Improvement 1995; 6(1):67-96.

Stringfield, S., Reynolds, D., & Schaffer, E.C. (2008). Improving secondary students' academic achievement through a focus on reform reliability: 4- and 9-year findings from the high reliability schools project, School Effectiveness and School Improvement; 19(4):409-428.

Suddaby, R. (2006). From the editors: What grounded theory is not. Academy of management journal, 49(4), 633-642.

Sutcliffe, K. M. (2011). High reliability organisations (HROs), Best Practice & Research Clinical Anaesthesiology, Volume 25, Issue 2, June, Pages 133-144, ISSN 1521-6896

Sutcliffe, K. M., Vogus, T. J., & Dane, E. (2016). Mindfulness in organisations: A cross-level review. Annual Review of Organisational Psychology and Organisational Behavior, 3, 55-81.

Taleb, N. N. (2010). The black swan: The impact of the highly improbable. London: Penguin Books

Tamuz, M., and Harrison, M. I. (2006). Improving safety in hospitals: Contributions of high reliability theory and normal accident theory, Health Research and Educational Trust, 41 (4), 1654-1673.

Tashakkori, A., & Teddlie, C. (2010). Sage handbook of mixed methods in social & behavioural research. New York: Sage.

Tasopoulou, K., & Tsiotras, G. (2017). Benchmarking towards excellence in higher education. Benchmarking: An International Journal, 24(3), 617-634.

Taylor, D. L., & Angelle, P. S. (2000). High reliability organisations and transformational leadership as lenses for examining a school improvement effort, Texas: Southwest Educational Research Association.

Taylor, N. Z., & Millear, P. M. R. (2016). The contribution of mindfulness to predicting burnout in the workplace. Personality and Individual Differences, 89, 123-128.

Temple, J., & Johnson, P. A. (1998). Social capability and economic growth. The Quarterly Journal of Economics, 113(3), 965-990.

Williams, M. (2000). Interpretivism and generalisation. Sociology, 34(2), 209-224.

Teddlie, C., & Tashakkori, A. (2006). A general typology of research designs featuring mixed methods. Research in the Schools, 13(1), 12-28.

Tsang, E. W. (2014). Case studies and generalization in information systems research: A critical realist perspective. The Journal of Strategic Information Systems, 23(2), 174-186.

Turner, B. A. (1978). Man-made disasters. London: Wykeham.

Turner, B. A. (1994). Causes of disaster: sloppy management. British Journal of Management, 5(3), pp.215- 219.

Turner, B. A., & Pidgeon, N. F. (1997). Man-made disasters (Vol. 2). Oxford: Butterworth-Heinemann.

Tversky, A., & Kahneman, D. (1975). Judgment under uncertainty: Heuristics and biases. In Utility, probability, and human decision making (pp. 141-162). Springer Netherlands

Tversky, A., Kahneman, D., & Moser, P. (1990). Judgment under uncertainty: Heuristics and biases. Rationality in action: Contemporary approaches 171-188.

UK Statutory Instruments (1992). Offshore Installations (Safety case) Regulations of 1992 Health and Safety No 2885 http://www.legislation.gov.uk/uksi/1992/2885/made retrieved 8th September 2017.

US Coast Guard (2010). Deepwater Horizon offshore production unit on fire, published by the US Coast Guard under Creative Commons public domain. Retrieved from https://commons.wikimedia.org/wiki/File:Deepwater_Horizon_offshore_drilling_unit_on_fire.jpg, April 3, 2018.

U.S. CSB (2005). US Chemical Safety and Hazard Investigation report - refinery fire and explosion. BP Texas City March 23, 2005

U.S. CSB (2007). Texas City incident diagram, published by the US Chemical Safety and Hazard Investigation Board under Creative Commons public domain. Retrieved from https://commons.wikimedia.org/wiki/File:BP_Texas_City_incident_diagram.png, April3, 2018.

U.S. CSB (2012) Texas City refinery explosion aftermath, published by the US Chemical Safety and Hazard Investigation Board under Creative Commons public domain. Retrieved from https://commons.wikimedia.org/wiki/File:BP_PLANT_EXPLOSION-1_lowres2.jpg, April 3, 2018

Uskarcı, A., & Demirörs, O. (2017). Do staged maturity models result in organisation-wide continuous process improvement? Insight from employees. Computer Standards & Interfaces, 52, 25-40.

Van der Vegt, G.S., Essens, P., Wahlström, M., & George, G. (2015). Managing risk and resilience. Academy of Management Journey, 58 (4), 971–980.

Van Maanen, J., Sørensen, J. B., & Mitchell, T. R. (2007). The interplay between theory and method. Academy of management review, 32(4), 1145-1154.

Van Teijlingen, E. R., & Hundley, V. (2001). The importance of pilot studies. Social Research Update, 35, http://hdl.handle.net/2164/15, Assessed Feb 2, 2018.

Vaughan, D. (1997). The Challenger launch decision: Risky technology, culture, and deviance at NASA. Chicago: University of Chicago Press.

Visser, (2010). Amoco Cadiz. http://www.aukevisser.nl/supertankers/part-1/id532.htm. Assessed June 13th, 2017.

Virtanen, I. (2015). In search for a theoretically firmer epistemological foundation for the relationship between tacit and explicit knowledge. Leading Issues in Knowledge Management, Volume Two, 2, 95.

Vlăsceanu, L., Grünberg, L. & Pârlea, D. (2004). Quality Assurance and Accreditation: A Glossary of Basic Terms and Definitions, pp. 25.Bucharest: UNESCO-CEPES.

Vogus, T. J., & Welbourne, T. M. (2003). Structuring for high-reliability: HR practices and mindful processes in reliability-seeking organisations, Journal of Organisational Behaviour, 24, 877-903.

Wahyuni, S. (2012). Qualitative research method: Theory and practice. Jakarta: Salemba Empat.

Waring, A. (2015). Managerial and non-technical factors in the development of human-created disasters: A review and research agenda. Safety science, 79, pp.254-267.

Weick, K. E. (1987). Organisational culture as a source of high reliability, California Management Review; 29: 112–127.

Weick K. E. & Putnam T. (2006). Organising for mindfulness: Eastern wisdom and Western knowledge. J. Management. Inq. 15:275–87.

Weick, K. E., and Roberts, K. H. (1993) Collective mind in organisations: Heedful interrelating on flight decks, Administrative Science Quarterly, 38 (3), 357-381.

Weick, K., Sutcliffe, K., & Obstfeld, D. (1999). Organising for high reliability: processes of collective mindfulness. Research in Organisational Behaviour, 21:81-123

Weick, K. & Sutcliffe, K. (2001). Managing the Unexpected: Assuring High Performance in an Age of Complexity, San Francisco: Jossey-Bass.

Weick, K. E., and Sutcliffe, K. M. (2007). Managing the unexpected: Resilient performance in an age of uncertainty, 2nd edn, San Francisco: Jossey-Bass.

Weick, K. E., & Sutcliffe, K. M. (2015). Managing the unexpected: sustained performance in a complex world. Hoboken, NJ: Wiley.

Wiles, R., Crow, G., & Pain, H. (2011). Innovation in qualitative research methods: A narrative review. Qualitative research, 11(5), 587-604.

WHO (2006). World Health Organisation report explains the health impacts of the world's worst-ever civil nuclear accident. World Health Organisation, 26 April 2006, http://www.who.int/mediacentre/news/releases/2006/pr20/en/, Retrieved 28 April, 2017.

Woods D. D. (2006). Essential characteristics of resilience for organisations. In Hollnagel, E., Woods ,D.D., Leveson, N., editors. Resilience engineering: concepts and precepts. Aldershot, UK: Ashgate. p. 21–34.

Woods, D. D. (2015). Four concepts for resilience and the implications for the future of resilience engineering. Reliability Engineering System Safety 141, 5–9.

World Bank (2017). Gender Data Portal – Nigeria. http://datatopics.worldbank.org/gender/country/nigeria. Retrieved July 12, 2017

World-Nuclear.org (2016) The 1986 Chernobyl accident, http://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/chernobyl-accident.aspx, Assessed 7th of July, 2017.

Yin, R. K. (2013). Case study research: Design and methods. New York: Sage publications.

84user (2010). A schematic illustration of a subsea blowout preventer stack installed on a seabed. Published by 84user, under Creative Commons public domain, Retrieved from https://commons.wikimedia.org/wiki/File:Subsea_blowout_preventer_stack_riser_mud.svg, April3, 2018

APPENDIX 1

Approval from the University Ethics Committee (E330)

This appendix shows the form E330, the approval from the ethics committee authorizing the research.

University of Portsmouth

Business School

Portsmouth Business School
University of Portsmouth
Richmond Building
Portland Street
Portsmouth
United Kingdom
PO1 3DE

T: +44 (0)23 9284 8484
W: www.port.ac.uk/pbs

26 January 2016

Agwu Emele Agwu

PhD Student, Portsmouth Business School, University of Portsmouth

Dear Agwu

Study Title:	**Applying High Reliability Organisations Theory to Improve Maturity of Organisations**
Ethics Committee reference:	**E330**

Thank you for submitting your documents for ethical review. The Ethics Committee was content to grant a favourable ethical opinion of the above research on the basis described in the application form, protocol and supporting documentation, revised in the light of any conditions set, subject to the general conditions set out in the attached document.

<u>The favourable opinion of the EC does not grant permission or approval to undertake the research. Management permission or approval must be obtained from any host organisation, including University of Portsmouth, prior to the start of the study.</u>

Summary of any ethical considerations

The Ethics Committee is content to grant a favourable ethical opinion subject to:

- One correction – that in Q7 you remove the phrase ‘and 10 from the defunct organisations’.

The Ethics Committee has made two recommendations:

- that you explain verbally to interviewees, before they sign the consent form, what the ability to 'withdraw at any time' actually means in practice, i.e. presumably at any time between the interview and whenever he starts analysing the data.
- that on the various documents you include a Portsmouth University telephone number (in addition to the Nigerian number) to make it clear that you are a bona fide member of the university.

Documents reviewed

The documents reviewed by Dr Debbie Reed [LCM]/Prof. Lisa Jack [Chair] + PBS Ethics Committee

Document	*Version*	*Date*
Ethical Review Application	1	29-Jan-15
Consent form	1	29-Jan-15
Consent form [interviews]	1	29-Jan-15
Cover letter	1	29-Jan-15
Introduction format for Interview Request	1	29-Jan-15
Introduction form for Telephone Interviews	1	29-Jan-15
Ethical Review Application	2	20-Dec-15
Ethical Review Application	3	28-Dec-15
Ethical Review Application	4	4-Jan-16
Ethical Review Application	5	14-Jan-16
Consent form	2	14-Jan-16
Consent form [Interviews]	2	14-Jan-16
Cover letter	2	14-Jan-16
Introduction format for Interview Request	2	14-Jan-16
Introduction format for Telephone Interviews	2	14-Jan-16
Introduction letter to proposed companies for questionnaire	2	14-Jan-16
Step by Step data collection process	2	14-Jan-16
Introduction letter for questionnaire	2	14-Jan-16
Ethical Review Application	6	21-Jan-16
Consent form	3	21-Jan-16
Consent form [interviews]	3	21-Jan-16
Cover letter	3	21-Jan-16
Data collection process flow chart	1	21-Jan-16
Introduction format for Interview Request	3	21-Jan-16
Introduction format for Telephone Interviews	3	21-Jan-16
Introduction letter for questionnaires	3	21-Jan-16
Introduction letter to proposed companies for questionnaire	3	21 Jan 1206
Questionnaire doc	1	21-Jan-16

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements set out by the University of Portsmouth

After ethical review

<u>Reporting and other requirements</u>

The attached document acts as a reminder that research should be conducted with integrity and gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Notification of serious breaches of the protocol
- Progress reports
- Notifying the end of the study

Feedback

You are invited to give your view of the service that you have received from the Faculty Ethics Committee. If you wish to make your views known please contact the administrator ***********

Please quote this number on all correspondence : E330

Yours sincerely and wishing you every success in your research

Lisa Jack

Chair

Email:

Enclosures:

"After ethical review – guidance for researchers"

Copy to: Prof. Ashraf Labib [Supervisor]

Appendix 1

After ethical review – guidance for researchers

This document sets out important guidance for researchers with a favourable opinion from a University of Portsmouth Ethics Committee. Please read the guidance carefully. A failure to follow the guidance could lead to the committee reviewing and possibly revoking its opinion on the research.

It is assumed that the research will commence within 3 months of the date of the favourable ethical opinion or the start date stated in the application, whichever is the latest.

The research must not commence until the researcher has obtained any necessary management permissions or approvals – this is particularly pertinent in cases of research hosted by external organisations. The appropriate head of department should be aware of a member of staff's research plans.

If it is proposed to extend the duration of the study beyond that stated in the application, the Ethics Committee must be informed.

If the research extends beyond a year then an annual progress report must be submitted to the Ethics Committee.

When the study has been completed the Ethics Committee must be notified.

Any proposed substantial amendments must be submitted to the Ethics Committee for review. A substantial amendment is any amendment to the terms of the application for ethical review, or to the protocol or other supporting documentation approved by the Committee that is likely to affect to a significant degree:

(a) the safety or physical or mental integrity of participants

(b) the scientific value of the study

(c) the conduct or management of the study.

A substantial amendment should not be implemented until a favourable ethical opinion has been given by the Committee.

Researchers are reminded of the University's commitments as stated in the Concordat to Support Research Integrity viz:

- maintaining the highest standards of rigour and integrity in all aspects of research
- ensuring that research is conducted according to appropriate ethical, legal and professional frameworks, obligations and standards
- supporting a research environment that is underpinned by a culture of integrity and based on good governance, best practice and support for the development of researchers
- using transparent, robust and fair processes to deal with allegations of research misconduct should they arise
- working together to strengthen the integrity of research and to reviewing progress regularly and openly

In ensuring that it meets these commitments the University has adopted the UKRIO Code of Practice for Research. Any breach of this code may be considered as misconduct and may be investigated following the University Procedure for the Investigation of Allegations of Misconduct in Research.

Researchers are advised to use the UKRIO checklist as a simple guide to integrity.

APPENDIX 2

Form UPR16 – Research Ethics Review Checklist

This appendix is the University of Portsmouth Form UPR16 showing the research ethics review checklist.

FORM UPR16

Research Ethics Review Checklist

Please include this completed form as an appendix to your thesis (see the Postgraduate Research Student Handbook for more information

Postgraduate Research Student (PGRS) Information			Student ID:	UP676926
PGRS Name:	AGWU EMELE AGWU			
Department:	OPERATIONS AND SYSTEMS MANAGEMENT	**First Supervisor:**	PROF. ASHRAF LABIB	
Start Date: (or progression date for Prof Doc students)		FEB 2013		

Study Mode and Route:	Part-time	☒	MPhil	☐	MD	☐
	Full-time	☐	PhD	☒	Professional Doctorate	☐

Title of Thesis:	Towards a Harmonized Framework for High Reliability Organisations
Thesis Word Count: (excluding ancillary data)	63,590

If you are unsure about any of the following, please contact the local representative on your Faculty Ethics Committee for advice. Please note that it is your responsibility to follow the University's Ethics Policy and any relevant University, academic or professional guidelines in the conduct of your study

Although the Ethics Committee may have given your study a favourable opinion, the final responsibility for the ethical conduct of this work lies with the researcher(s).

UKRIO Finished Research Checklist:
(If you would like to know more about the checklist, please see your Faculty or Departmental Ethics Committee rep or see the online version of the full checklist at: http://www.ukrio.org/what-we-do/code-of-practice-for-research/)

a) Have all of your research and findings been reported accurately, honestly and within a reasonable time frame?	YES NO	☐ ☐
b) Have all contributions to knowledge been acknowledged?	YES NO	☒ ☐
c) Have you complied with all agreements relating to intellectual property, publication and authorship?	YES NO	☒ ☐
d) Has your research data been retained in a secure and accessible form and will it remain so for the required duration?	YES NO	☒ ☐
e) Does your research comply with all legal, ethical, and contractual requirements?	YES NO	☒ ☐

Candidate Statement:

I have considered the ethical dimensions of the above named research project, and have successfully obtained the necessary ethical approval(s)

Ethical review number(s) from Faculty Ethics Committee (or from NRES/SCREC):	E330

If you have *not* submitted your work for ethical review, and/or you have answered 'No' to one or more of questions a) to e), please explain below why this is so:

UPR16 – August 2015

Signed *(PGRS)*:	Agwu Emele Agwu	**Date:** Jan 18, 2018

APPENDIX 3

Sample Questionnaire

This appendix shows a sample of the questionnaire used for the research. It is a pdf download from sogosurvey, the online survey instrument used for the survey.

University of Portsmouth

Applying the High Reliability Organisation Theory to Improve the Maturity of Organisations - A PhD Thesis

page 1

1. COVER LETTER

Dear Sir/Madam,

Thank you for accepting to participate in this survey.

This questionnaire is part of a research project to improve the maturity of organizations using the High Reliability Organizations theory. Your responses are very important and will help deepen understanding about the extent to which different organizations exhibit the behaviours of High Reliability Organizations (HROs). It will ultimately help the research to develop a framework to assess the maturity of organizations with respect to the HRO theory and thereby assist organizations to sustain or improve their maturity levels to enhance sustainability and productivity.

I must emphasize that this questionnaire is entirely voluntary and it is up to you to decide whether or not you wish to take part. Proceeding implies informed consent.

Let me assure you that all information you provide will be treated with the strictest confidence. You will notice that you have not been asked to include your name and address anywhere on the questionnaire. Your answers and others will be used as the main data set for this research. In addition to your anonymity, the information will be stored and secured on an encrypted and locked hard drive with backup stored on the N Drive. All data will first be grouped and coded, while the code identifiers will be stored separately.

The questionnaire focuses on five key areas (described on page 2) and should take 5 to 10 minutes to complete

Thank you for your anticipated assistance

page 2

2. Introduction to High Reliability Organization Theory

High Reliability Organizations operate in highly hazardous environments with complex technologies, where minor lapses in judgment would result in catastrophic failures, yet continue to operate at top quartile level. These organizations have evolved over time to become well equipped to prevent catastrophic failures, withstand the consequences of eventual failures should they occur, and re-engineer themselves for future competitiveness.
Research in the High Reliability Organizations Theory began at the University of California at Berkley, and has grown to become a body of knowledge. Research has shown that these organizations think and act differently from most others and have different processes and practices.
At the core of their practices are five key behaviours: Preoccupation to Failure: They pay close attention to weak signals of failure and view near misses as symptoms of larger problems within the system rather than proof of effective safeguards in the system Reluctance to Simplify: They avoid undue generalizations on how and why things work or fail. They probe deeper, and ask more questions to get to root causes. Sensitivity to Operations: They are constantly responsive to the details of their operations, with the right staffing, competence levels and motivation, and are able to detect and competently react to slight changes in the process. Commitment to Resilience: Their leaders and employees are competent and prepared to respond to failures despite the vagaries of external influences. They are also able to recover from the effects of

failures, and apply the learnings from the failures. Deference to Expertise: Their leaders and supervisors are prepared to put hierarchy apart and respond to the insights from the experienced and competent staff despite their positions within the organization. The short questions in pages 4 to 8 will revolve around these five key behaviours.

3. INSTRUCTIONS:
Please select the answer you consider most appropriate from the given options based on your perceptions of your organization.
Please use the following scale. Score Strongly Agree 5 Partially Agree 4 Neither Agree nor Disagree 3 Partially Disagree 2 Strongly Disagree 1 There is also a column for rank at the end of each section. For each section, rank the questions in order of how important you think the questions are in relation to the section. Assign 1 to the most important. This will also help to assign weights to the scores.

page 3

4. Demographics

5. Industry Type (Please choose closest) (Select one option)

- ◯ Academia
- ◯ Petroleum
- ◯ Construction
- ◯ Nuclear
- ◯ Health Care
- ◯ Food & Beverages Manufacturing
- ◯ Consultancy
- ◯ Engineering
- ◯ Hotels and Restaurants (Hospitality)
- ◯ Banking
- ◯ Mines & Power
- ◯ Transportation and Aviation
- ◯ Other (Please specify) ____________

6. Name of Organization

(a)

7. Primary Responsibility (Please choose closest) (Select one option)

- ◯ Management
- ◯ Supervisor
- ◯ Front line Staff

8. Years of Experience (Select one option)

- ◯ Below 3 Years
- ◯ 3 Years to 7 Years
- ◯ Above 7 Years and Below 15 Years
- ◯ 15 Years to 25 Years
- ◯ Above 25 Years

9. Gender (Select one option)

- Male
- Female

page 4

10. SECTION 1: ASSESSING
PREOCCUPATION WITH FAILURE

This section assesses your organisation's perception of failure. Highly reliable organisations pay very close attention to weak signals of failure. They view near misses as symptoms of larger problems within the system, rather than proof of effective safeguards in the system.

11. We are encouraged to report near misses (Select one option)

- 5 - Strongly Agree;
- 4 - Partially Agree;
- 3 - Neither Agree nor Disagree;
- 2 - Partially Disagree;
- 1 - Strongly Disagree
- Other (Please explain) ___________

12. We are encouraged to report incidents (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please explain) ___________

13. We regard near misses as potential failures (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 2 - Strongly Disagree
- Other (Please explain) ___________

14. We regard near misses as indications of our system health (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please explain) ___________

15. We maintain a database of incidents and potential failures, not our ability to avoid failures (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree

- ◯ 2 - Partially Disagree
- ◯ 1 - Strongly Disagree
- ◯ Other (Please explain) ____________

16. We perform a root cause analysis for all incidents and potential failures (Select one option)

- ◯ 5 - Strongly Agree
- ◯ 4 - Partially Agree
- ◯ 3 - Neither Agree nor Disagree
- ◯ 2 - Partially Disagree
- ◯ 1 - Strongly Disagree
- ◯ Other (Please specify) ____________

17. We apply learning from incidents and potential failures to update our procedures (Select one option)

- ◯ 5 - Strongly Agree
- ◯ 4 - Partially Agree
- ◯ 3 - Neither Agree nor Disagree
- ◯ 2 - Partially Disagree
- ◯ 1 - Strongly Disagree
- ◯ Other (Please specify) ____________

18. We focus more on failure than successes (Select one option)

- ◯ 5 - Strongly Agree
- ◯ 4 - Partially Agree
- ◯ 3 - Neither Agree nor Disagree
- ◯ 2 - Partially Disagree
- ◯ 1 - Strongly Disagree
- ◯ Other (Please specify) ____________

19. We actively consider worst case scenarios in our plans and analyses (Select one option)

- ◯ 5 - Strongly Agree
- ◯ 4 - Partially Agree
- ◯ 3 - Neither Agree nor Disagree
- ◯ 2 - Partially Disagree
- ◯ 1 - Strongly Disagree
- ◯ Other (Please specify) ____________

20. We often review our activities at intervals to actively seek potential hot spots (Select one option)

- ◯ 5 - Strongly Agree
- ◯ 4 - Partially Agree
- ◯ 3 - Neither Agree nor Disagree
- ◯ 2 - Partially Disagree
- ◯ 1 - Strongly Disagree
- ◯ Other (Please specify) ____________

21. We do not victimize people who make mistakes (Select one option)

- ◯ 5 - Strongly Agree
- ◯ 4 - Partially Agree

- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ___________

22. We actively reward personnel who own up to mistakes or near misses (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ___________

23. We feel free to talk to our superiors about problems (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ___________

24. Our superiors freely talk to us about problems (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ___________

25. Our superiors actively seek out bad news about potential issues (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ___________

26. Please rank the questions in the order of importance to you. Use 1 for the most important and 15 for the least important. [**Please select exactly 15 options.**]

We are encouraged to report near misses	
We are encouraged to report incidents	
We regard near misses as potential failures	
We regard near misses as indications of our system health	
We maintain a database of incidents and potential failures, not our ability to avoid failures	
We perform a root cause analysis for all incidents and potential failures	
We apply learning from incidents and potential failures to update our procedures	

We focus more on failure than successes	
We actively consider worst case scenarios in our plans and analyses	
We often review our activities at intervals to actively seek potential hot spots	
We do not victimize people who make mistakes	
We actively reward personnel who own up to mistakes or near misses	
We feel free to talk to our superiors about problems	
Our superiors freely talk to us about problems	
Our superiors actively seek out bad news about potential issues	

page 5

27. **SECTION 2: ASSESSING**

RELUCTANCE TO SIMPLIFY

This section assesses how your organisation balances simplification and standardization of processes with actively seeking to avoid undue generalizations on how and why things work or fail. Highly reliable organisations have standardized processes. They however put a lot of emphasis on probing deeper, and asking more questions to get to root causes of failures or potential failures.

28. We encourage people to challenge procedures and processes (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ___________

29. We reward people who think outside the box (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ___________

30. We do not victimize people who challenge the norm (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ___________

31. We are not attacked when we report information that could disrupt operations (Select one option)

- 5 - Strongly Agree;
- 4 - Partially Agree;
- 3 - Neither Agree nor Disagree;
- 2 - Partially Disagree;

○ 1 - Strongly Disagree
○ Other (Please specify) ____________

32. We respect different view points (Select one option)

○ 5 - Strongly Agree
○ 4 - Partially Agree
○ 3 - Neither Agree nor Disagree
○ 2 - Partially Disagree
○ 1 - Strongly Disagree
○ Other (Please specify) ____________

33. We value constructive criticisms (Select one option)

○ 5 - Strongly Agree
○ 4 - Partially Agree
○ 3 - Neither Agree nor Disagree
○ 2 - Partially Disagree
○ 1 - Strongly Disagree
○ Other (Please specify) ____________

34. We value skeptics (Select one option)

○ 5 - Strongly Agree
○ 4 - Partially Agree
○ 3 - Neither Agree nor Disagree
○ 2 - Partially Disagree
○ 1 - Strongly Disagree
○ Other (Please specify) ____________

35. We trust one another (Select one option)

○ 5 - Strongly Agree
○ 4 - Partially Agree
○ 3 - Neither Agree nor Disagree
○ 2 - Partially Disagree
○ 1 - Strongly Disagree
○ Other (Please specify) ____________

36. We encourage people to deepen their understanding of the process to better challenge it. (Select one option)

○ 5 - Strongly Agree
○ 4 - Partially Agree
○ 3 - Neither Agree nor Disagree
○ 2 - Partially Disagree
○ 1 - Strongly Disagree
○ Other (Please specify) ____________

37. We encourage people deepen their analyses to better grasp the nature of problems that arise (Select one option)

○ 5 - Strongly Agree
○ 4 - Partially Agree
○ 3 - Neither Agree nor Disagree
○ 2 - Partially Disagree

- 1 - Strongly Disagree
- Other (Please specify) ____________

38. We are encouraged to listen carefully to other view points (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ____________

39. Everyone's views rarely go unheard.
(Select one option)

- 5. Strongly Agree
- 4. Partially Agree
- 3. Neither Agree nor Disagree
- 2. Partially Disagree
- 1. Strongly Disagree
- Other (Please specify) ____________

40. Please rank the questions in the order of importance to you. Use 1 for the most important and 12 for the least important.
[Please rank all option(s).]

We encourage people to challenge procedures and processes	
We reward people who think outside the box	
We do not victimize people who challenge the norm	
We are not attacked when we report information that could disrupt operations	
We respect different view points	
We value constructive criticisms	
We value skeptics	
We trust one another	
We encourage people to deepen their understanding of the process to better challenge it.	
We encourage people deepen their analyses to better grasp the nature of problems that arise	
We are encouraged to listen carefully to other view points	
Everyone's views rarely go unheard.	

page 6

41. SECTION 3: ASSESSING SENSITIVITY TO OPERATIONS This section assesses your organsaition's sensitivity to operations. Highly reliable organisations are constantly responsive to the details of their operations, with the right staffing, competence levels and motivation, and able to detect and competently react to slight changes in the process.

42. Everyone has overview about the overall organization's operations (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree

- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ___________

43. We hold regular team meetings to ensure everyone knows what everyone is doing (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ___________

44. We assist other teams outside our own jobs (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ___________

45. Our managers constantly monitor our day to day activities (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ___________

46. Our managers make inputs to our day to day activities as required (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ___________

47. Someone with authority is readily available to frontline for prompt decision making (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ___________

48. Everyone is expected to take decision, such as operations shutdown to forestall catastrophic failure (Select one option)

- 5 - Strongly Agree

- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ____________

49. People have discretion to resolve unexpected frontline problems without differing to leadership (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ____________

50. There is constant open communication between leadership and frontline, to build a clear picture of current situations (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ____________

51. There is constant open communication among all staff to build a clear picture of current situations (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ____________

52. Resources are readily available to manage unexpected issues (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ____________

53. Please rank the questions in the order of importance to you. Use 1 for the most important and 11 for the least important. [Please select exactly 11 options.]

Please rank the questions in the order of importance to you. Use 1 for the most important and 12 for the least important.	
We hold regular team meetings to ensure everyone knows what everyone is doing	
We assist other teams outside our own jobs	
Our managers constantly monitor our day to day activities	
Our managers make inputs to our day to day activities as required	

Someone with authority is readily available to front line for prompt decision making	
Everyone is expected to take decision, such as operations shutdown to forestall catastrophic failure	
People have discretion to resolve unexpected front line problems without differing to leadership	
There is constant open communication between leadership and front line, to build a clear picture of current situations	
There is constant open communication among all staff to build a clear picture of current situations	
Resources are readily available to manage unexpected issues	

page 7

54.
COMMITMENT TO RESILIENCE **SECTION 4: ASSESSING**

This section assesses your organisation's committment to resilience. Leaders and employees in highly reliable organisations are competent and prepared to respond to failures despite the vagaries of external influences. They are also able to quickly recover from the effects of failure, and apply the learning from it.

55. My organization places high emphasis on technical competence development (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ________

56. My organization places high emphasis on attitude and behavioral competences (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ________

57. Our competencies are assessed regularly assessed (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ________

58. We have the skills required to act should unexpected problems arise (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ________

59. We have well defined emergency response plans (Select one option)

- ○ 5 - Strongly Agree
- ○ 4 - Partially Agree
- ○ 3 - Neither Agree nor Disagree
- ○ 2 - Partially Disagree
- ○ 1 - Strongly Disagree
- ○ Other (Please specify) ___________

60. Most people are aware of the details of our emergency response plans (Select one option)

- ○ 5 - Strongly Agree
- ○ 4 - Partially Agree
- ○ 3 - Neither Agree nor Disagree
- ○ 2 - Partially Disagree
- ○ 1 - Strongly Disagree
- ○ Other (Please specify) ___________

61. We have well defined contingency plans (Select one option)

- ○ 5 - Strongly Agree
- ○ 4 - Partially Agree
- ○ 3 - Neither Agree nor Disagree
- ○ 2 - Partially Disagree
- ○ 1 - Strongly Disagree
- ○ Other (Please specify) ___________

62. Most people are aware of the organization's contingency plans (Select one option)

- ○ 5 - Strongly Agree
- ○ 4 - Partially Agree
- ○ 3 - Neither Agree nor Disagree
- ○ 2 - Partially Disagree
- ○ 1 - Strongly Disagree
- ○ Other (Please specify) ___________

63. We conduct regular drills to enhance preparedness in case of unexpected problems (Select one option)

- ○ 5 - Strongly Agree
- ○ 4 - Partially Agree
- ○ 3 - Neither Agree nor Disagree
- ○ 2 - Partially Disagree
- ○ 1 - Strongly Disagree
- ○ Other (Please specify) ___________

64. We have a number of key formal contacts we sometimes use to solve problems (Select one option)

- ○ 5 - Strongly Agree
- ○ 4 - Partially Agree
- ○ 3 - Neither Agree nor Disagree
- ○ 2 - Partially Disagree
- ○ 1 - Strongly Disagree

- Other (Please specify) ___________

65. We have a number of key informal contacts we sometimes use to solve problems (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ___________

66. There is a high level of shared trust among all staff and management (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ___________

67. Please rank the questions in the order of importance to you. Use 1 for the most important and 12 for the least important. [**Please select exactly 12 options.**]

Please rank the questions in the order of importance to you. Use 1 for the most important and 12 for the least important.	
My organization places high emphasis on attitude and behavioral competences	
Our competencies are assessed regularly assessed	
We have the skills required to act should unexpected problems arise	
We have well defined emergency response plans	
Most people are aware of the details of our emergency response plans	
We have well defined contingency plans	
Most people are aware of the organization's contingency plans	
We conduct regular drills to enhance preparedness in case of unexpected problems	
We have a number of key formal contacts we sometimes use to solve problems	
We have a number of key informal contacts we sometimes use to solve problems	
There is a high level of shared trust among all staff and management	

page 8

68. **SECTION 5: ASSESSING**

DEFERENCE TO EXPERTISE

This section assesses by how much the leaders and supervisors in your organisation are prepared to put hierarchy apart and respond to the insights from the experienced and competent staff despite their position within the organisation.

69. People respect the nature of one another's jobs (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree

○ 1 - Strongly Disagree
○ Other (Please specify) ___________

70. People are committed to doing their job well (Select one option)

○ 5 - Strongly Agree
○ 4 - Partially Agree
○ 3 - Neither Agree nor Disagree
○ 2 - Partially Disagree
○ 1 - Strongly Disagree
○ Other (Please specify) ___________

71. People in the organization value expertise and experience over rank (Select one option)

○ 5 - Strongly Agree
○ 4 - Partially Agree
○ 3 - Neither Agree nor Disagree
○ 2 - Partially Disagree
○ 1 - Strongly Disagree
○ Other (Please specify) ___________

72. We are encouraged to take expert decisions irrespective of hierarchy (Select one option)

○ 5 - Strongly Agree
○ 4 - Partially Agree
○ 3 - Neither Agree nor Disagree
○ 2 - Partially Disagree
○ 1 - Strongly Disagree
○ Other (Please specify) ___________

73. In an emergency, the most experienced in that emergency takes the lead (Select one option)

○ 5 - Strongly Agree
○ 4 - Partially Agree
○ 3 - Neither Agree nor Disagree
○ 2 - Partially Disagree
○ 1 - Strongly Disagree
○ Other (Please specify) ___________

74. Expertise for all jobs is readily available when required (Select one option)

○ 5 - Strongly Agree
○ 4 - Partially Agree
○ 3 - Neither Agree nor Disagree
○ 2 - Partially Disagree
○ 1 - Strongly Disagree
○ Other (Please specify) ___________

75. People generally know who has the expertise for different jobs (Select one option)

○ 5 - Strongly Agree
○ 4 - Partially Agree
○ 3 - Neither Agree nor Disagree
○ 2 - Partially Disagree
○ 1 - Strongly Disagree
○ Other (Please specify) ___________

76. People typically feel responsible for problems until they are resolved (Select one option)

- 5 - Strongly Agree
- 4 - Partially Agree
- 3 - Neither Agree nor Disagree
- 2 - Partially Disagree
- 1 - Strongly Disagree
- Other (Please specify) ____________

77. Please rank the questions in the order of importance to you. Use 1 for the most important and 8 for the least important. [Please select exactly 8 options.]

People respect the nature of one another's jobs	
People are committed to doing their job well	
People in the organization value expertise and experience over rank	
We are encouraged to take expert decisions irrespective of hierarchy	
In an emergency, the most experienced in that emergency takes the lead	
Expertise for all jobs is readily available when required	
People generally know who has the expertise for different jobs	
People typically feel responsible for problems until they are resolved	

Operations and Systems Management Group, Richmond Building, Portland Street, The University of Portsmouth, PO1 3DE, Portsmouth, United Kingdom. agwu.agwu@myport.ac.uk

APPENDIX 4

A sample of the Interview Questions

This appendix shows a sample of the interview questions used in this researched.

A sample of the Interview Questions

Towards a Harmonized Framework for High Reliability Organisations – A Ph.D Thesis

Interview Questions

SECTION 1: Demographics

1. Gender:
2. Industry:
3. Organisation:
4. Primary Responsibility:
5. Years of Experience:

SECTION 2: Assessing Preoccupation with Failure

1. How does your organisation manage near misses
2. How does your organisation manage incidents
    a. Follow up to confirm reporting, and perceptions about near misses and incidents
    b. Follow up with questions about incident database management
3. What processes do you have in place to prevent recurrences
    a. Follow up questions analysis
    b. Follow up questions on learning from incident processes
    c. Follow up questions on using worst case scenarios during planning and analyses
    d. Follow up questions on actively seeking out potential hot spots
4. Where do you focus more: successes or failures, and why?
5. How does the organisation manage people that make mistakes?
6. What form of communication exists between management and staff?
7. What has been your personal experience with regards failure

SECTION 3: Assessing Reluctance to Simplify

1. Do you have sceptics in your organisation? How are they perceived?
2. What is the perception and behaviour towards people that challenge the process?
3. What would your organisation typically do to someone that disrupts operations? Why?
4. What is the organisation's attitude towards learning?

    a. Follow up with deepening understanding to better challenge the process
5. What is your impression about the level of trust between one another?
6. To what extent are everyone's viewpoints heard and taken into consideration?
7. Have you taken something for granted that turned out to lead to failure? Have you seen it within your organisation? What happened? What was the effect?

SECTION 4: Assessing Sensitivity to Operations

1. What is the nature of our team meetings?
    a. Frequency, usefulness, participation, terms of reference
2. To what level do superiors and managers intervene in daily activities? How is this perceived by the employees?
3. What is the nature of your feedback process?
4. What about field supervision? How much of this is readily available? How much can field leadership take decisions without deferring to management?
5. If someone interrupts the process to forestall a catastrophic failure, what would happen? What if it turns out to be a false alarm?
6. What form of communication is available between frontline and management, and among staff

SECTION 5: Assessing Commitment to Resilience

1. What emergency response and contingency processes are available?
2. How do people respond to these processes?
3. How much skills are available within my organisation?
4. How are these skills assessed?
5. What type of emergencies have you had in your organisation?
6. How were the emergencies managed?
7. What were the effects? Lessons learned?

SECTION 6: Assessing Deference to Expertise

1. Have you experienced emergencies within your organisation? Who took the lead?
2. In that emergency, what was the relationship between the experienced people and the management staff? Who was in charge? How did they resolve issues after the emergency?
3. What level of expertise is available in your team? How do you spot who has the expertise at each time?

APPENDIX 5

Journal paper submitted to Journal of Safety Science

This appendix shows the abstract of the paper presented to the Journal of Safety Science

Appendix 5: Journal paper submitted to Journal of Safety Science

Manuscript Details

Manuscript number	SAFETY_2017_1716
Title	Disaster Prevention through a harmonized Framework for High Reliability Organisations
Article type	Research Paper

Abstract

The increasing havoc wrecked by catastrophic incidents on organisations worldwide, as well as the increasing devastating effects of these incidents, has necessitated the development of a framework to improve the reliability of organisations. Despite operating in tightly coupled and complex technologies, high reliability organisations (HROs) continue to operate mindfully with minimal incidents. Given that most disasters have occurred in organisations and industries not considered as truly HROs, this paper argues that applying organisational learning from HROs across diverse organisations in different industries could potentially reduce organisational disasters. This paper recognised the numerous researches in HRO theory, but noticed the unavailability of a harmonized measurable framework that could be standardized and applied across diverse organisations. Using the HRO principles, this paper conducted a research in 8 organisations, in 3 industries across 2 continents. It developed the organisational reliability maturity model (ORM2) to track the progression organisations through 5 maturity levels. It developed the framework for organisational reliability maturity (FORM) to measure maturity levels of organisations, predict potentials for disasters, benchmark, and improvement organisations. It is hoped that this paper will deepen existing research in disaster prevention and HRO theory, while opening up new areas of knowledge.

Keywords	Disasters; Organisational Learning; High Reliability Organisations; Maturity; Bench-marking; Organisational Improvement Framework
Taxonomy	Organizational Failure, Organizational Effectiveness, Developing Organizational Maturity, Organisational Resilience, Disaster Management, Organisational Learning
Manuscript region of origin	Africa

Corresponding Author	Agwu Emele Agwu
Corresponding Author's Institution	University of Portsmouth
Order of Authors	Agwu Emele Agwu, Ashraf Labib, Sara Hadleigh-Dunn (Thorne)

Submission Files Included in this PDF

File Name [File Type]

Cover Letter.docx [Cover Letter]

Highlights.docx [Highlights]

Abstract.docx [Abstract]

Copy-of-Title Page.docx [Title Page (with Author Details)]

Disaster Prevention through a harmonized Framework for HROs.docx [Manuscript (without Author Details)]

To view all the submission files, including those not included in the PDF, click on the manuscript title on your EVISE Homepage, then click 'Download zip file'.

Research Data Related to this Submission

Data set	https://data.mendeley.com/datasets/64y2278mzd/draft?a=29f47642-80ba-45ae-9e4b-a8ad6b2b5c08

Data for: Disaster Prevention through a harmonized Framework for High Reliability Organisations

The questionnaire template is a copy of the questionnaire from which the online survey instrument was extracted. The questionnaire summary is a summary of all the responses obtained by this research.